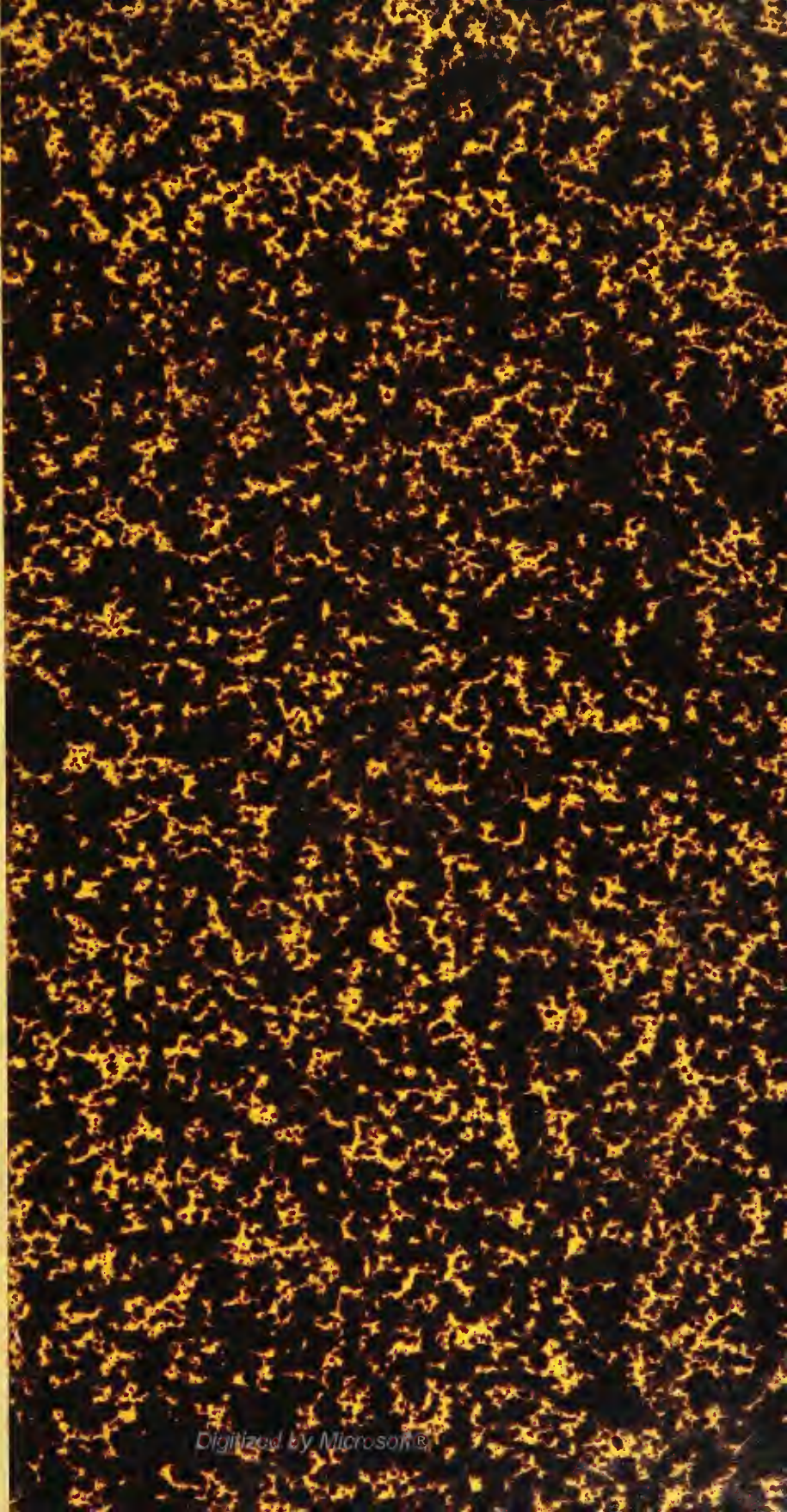

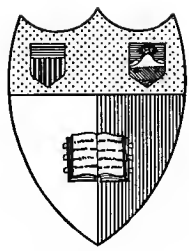

MEMOIRS OF THE GEOLOGICAL SURVEY.
SCOTLAND.

THE GEOLOGY
OF
GLENELG, LOCHALSH
AND
SOUTH-EAST PART OF SKYE.
(EXPLANATION OF ONE-INCH MAP 71.)

BY

B. N. PEACH, LL.D., F.R.S.; JOHN HORNE, LL.D., F.R.S.;
H. B. WOODWARD, F.R.S., F.G.S.; C. T. CLOUGH, M.A., F.G.S.;
ALFRED HARKER, M.A., F.R.S.;
AND C. B. WEDD, B.A., F.G.S.

WITH CONTRIBUTIONS BY

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Beinn a' Chapuill from the Mouth of the Little Glen (Glean Beag) of Glenelg. The crags near the top of the hill are chiefly composed of siliceous schist belonging to the Moine series. A thin ledge near the bottom of the crags and most of the lower hills in the foreground are composed of rocks of the Lewisian Gneiss series.

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MEMOIRS OF THE GEOLOGICAL SURVEY.
SCOTLAND.

THE GEOLOGY
OF
GLENELG, LOCHALSH
AND
SOUTH-EAST PART OF SKYE.

(EXPLANATION OF ONE-INCH MAP 71.)

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PREFACE.

This Memoir deals with the geology of the area included in Sheet 71 of the one-inch map of Scotland and, together with the map, embodies the results of field-work carried on during the years 1892–1901, under the general supervision of Dr. B. N. Peach as District Geologist.

Dr. Peach, in conjunction with Dr. J. Horne, surveyed the district of Loch Alsh and the Crowlin Islands. Mr. C. T. Clough mapped Glenelg and most of the pre-Triassic rocks of Skye. Mr. H. B. Woodward, Mr. G. Barrow and Mr. C. B. Wedd mapped nearly all the Mesozoic rocks; the largest share of the field-work falling to the last-mentioned officer, who is also mainly responsible for the description of these rocks. Mr. A. Harker surveyed most of the area occupied by the Tertiary igneous rocks and also considerable tracts of Torridonian and Cambrian rocks in Scalpa and in the part of Skye west of Broadford.

The important belt of country affected by the post-Cambrian thrusts and folds is treated somewhat briefly in the following pages, because it has already been described at considerable length in the general memoir on "The Geological Structure of the North-West Highlands," to which reference may be made for fuller details. The Tertiary igneous rocks are also treated briefly as they have been dealt with by Mr. Harker in his Memoir on "The Tertiary Igneous Rocks of Skye."

The schists and gneisses which lie east of the Moine thrust, and which include both Lewisian and Moine rocks, have, on the other hand, been described in considerable detail on account of certain features of peculiar interest. The Lewisian Gneiss in this area is composed not only of ortho-gneisses, but also of thick bands of limestone and various gneisses of sedimentary origin. Notwithstanding the fact that the original relations of the Lewisian Gneiss to the Moine Series have been much obscured by folding and shearing, some evidence has been noted which appears to indicate that the Moine sediments were laid down unconformably on the Lewisian Gneiss.

The relation of the Moine schists to the Torridon Sandstone in the area represented by Sheet 71 has been carefully considered. Various facts described in this Memoir suggest that the former schists may be altered representatives of beds belonging to the Torridonian formation, but no definite conclusion on this question has been reached.

The detailed examination of the Mesozoic rocks has proved their similarity both palæontologically and lithologically, to the common Mesozoic types in England, and established the completeness of the sequence up to the Corallian clays. No evidence of the presence of any higher Jurassic or Lower Cretaceous strata has been found though Upper Cretaceous rocks occur. There are, indeed, good grounds for

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believing that earth-movements, resulting in the production of some great faults, took place after the formation of the Jurassic, and before the deposition of the Upper Cretaceous strata. Professor Judd long ago pointed out the great unconformity at the base of the Upper Cretaceous rocks in the West Highlands.

The Appendix contains a list of Mesozoic fossils collected during the progress of the work. This list has been drawn up by Dr. F. L. Kitchin and Mr. C. B. Wedd: nearly all the ammonites have been recently examined and named by Mr. S. S. Buckman. The Appendix includes also a list of Cambrian fossils which has been compiled by Dr. Peach from specimens collected for the most part by Mr. A. Macconochie. A list of species from a raised beach at the head of Loch na Dal, Skye, has been kindly drawn up for the Survey by Mr. Thos. Scott. The bibliographical list of works relating to the geology of the district has been compiled by Mr. D. Tait.

The Plates are all from photographs taken by Mr. R. Lunn. Mr. C. T. Clough has acted as editor.

J. J. H. TEALL,
Director.

Geological Survey Office,
28 Jermyn Street, London,
9th July 1910.

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THE GEOLOGY OF GLENELG, LOCHALSH AND SOUTH-EAST PART OF SKYE.

CHAPTER I.

INTRODUCTION.

Area and Physical Features.

The one-inch Sheet to be described includes the south-eastern portion of the Isle of Skye, extending from the Red Hills and the outlying eastern portion of the Cuillin Hills to the Sound of Sleat, together with Scalpa, Pabba * and many smaller islands. The mainland of Ross and Inverness enters into the eastern half, but is cut into different divisions by Loch Alsh, Loch Hourn, Loch Duich and Loch Long.†

The land area is not much larger than that of the sea, and is so divided by sea-lochs and "sounds" that no part is more than four miles from the shore. The longer of these arms of the sea are divisible into two classes proceeding nearly at right angles to one another: the one class, represented by the Sound of Sleat, Loch Long and Loch Eishort, stretching in a N.N.E. direction, parallel to the general strike of the rocks; while the other, represented by Loch Duich, Loch Alsh and Loch Hourn, crosses the strike almost at right angles. Some of these arms can be followed outside the area of the map up to the mouth of long deep glens which have nearly the same directions as themselves, and there can be little doubt that they represent the sites of drowned valleys which were occupied by rivers in comparatively recent geological times, when the general elevation of the district was much higher above the sea than at present. The floors of these old valleys do not, indeed, slope uniformly in one direction away from the mountains, but this fact is probably explainable on the supposition that certain parts have been "over-deepened" by ice action, so as to form rock basins.

At the west end of Glas Eilean the greatest depth of Loch Alsh

* In the one-inch map these islands are spelt "Scalpay" and "Pabay," but it seems unwise in this explanation to change names which have been so long known to geologists.

† The two last-mentioned lochs are not named in this one-inch map. They are the two sheets of water which proceed from the eastern end of Loch Alsh, namely, Loch Long, striking N.N.E., and Loch Duich, striking S.S.W.

is only nine fathoms (Admiralty Chart 3292), though further east and south-east, in Loch Duich, two basins exceed 50 fms. (Plate xxxv. Royal Scottish Geographical Society's Atlas of Scotland). A mile south-west of Balmacara the depth is 62 fms., but further west, between the Plock of Kyle and Bogha Beag, and between this last islet and the nearest part of Skye, seven fathoms is the most recorded. The maximum depth in the "Narrows" of Kyle Rhea is 19 fms., but about 600 yds. south of the ferry it is only 10 fms. About half way between the foot of the Gleann Beag of Glenelg and Dun Ruaige, the depth is 75 fms., but further south-west, between Loch na Dal and the Sandaig Islands, the greatest depth recorded is 48 fms. (Admiralty Chart 2507). At the mouth of Loch Hourn the greatest depth is 87 fms., but further south-west, about a mile south of the south margin of the map being described, it is 52 fms.

The relative ages of these two valley systems are not known with certainty, but it is presumed that both are later than the Tertiary dykes, for otherwise basaltic sheets would in all probability have flowed into these valleys from some of the dyke-fissures, and would have still left some evidence of their former existence.

The larger lochs and valleys which strike west or W.N.W. may, according to a suggestion of Prof. Mackinder,* be regarded as representatives of valleys which once drained eastward right across the northern Highlands. According to this theory the streams which originated these great hollows may have arisen in mountains of Tertiary igneous rocks, which in part are now represented by denuded remnants in Skye and in part have been depressed out of sight beneath the sea by later earth-movements. A depression in a western area may have caused a reversal of the drainage in the western parts of these big hollows, and may also have given such a stimulus to the denuding powers of the streams flowing westward, in the western area, that they began to eat back rapidly in an easterly direction and captured many streams which but recently drained eastward.

A considerable part of the district is rugged and mountainous, and the higher hills stand out in picturesque detached forms. They resemble those often seen in high Alpine countries, and have probably been carved out from the neighbouring masses by prolonged subaerial denudation, during the times, just referred to, when the general elevation was greater than now. Ben Sgriol (3196 ft.), on the mainland north of Loch Hourn, is the highest hill, but yields place in rugged grandeur to Blath-bheinn, familiarly known as "Blaven" (3042 ft.), which is considered by many to be the finest mountain in Britain. Between Ben Sgriol and the mainland mountains on the east side, and Blaven on the west, a less rugged and less elevated tract stretches in a south-west direction from the north-east corner of the map, and forms the eastern peninsula of Skye.

In consequence of the westerly position near the Atlantic sea-board the rainfall is unusually heavy. In portions of the Cuillin Hills the annual fall is considered to be the greatest in Europe, exceeding 150 in., and in the mountains near the head of Loch Hourn it is probably not much less. In the south-eastern peninsula of Skye it is, however, more moderate, as is shown by the third and

* "Britain and the British Seas," p. 133. Oxford, 1907.

fourth lines of the following table of averages for the three years 1901–1903 :—*

At Strathaird	94·33 in.
„ Scalpay	74·83 „
„ Kyleakin	50·06 „
„ Isle Ornsay	40·55 „
„ Glenelg Manse	64·18 „

April, May, and June appear to be generally the least wet months.†

The whole of the land drains into the Atlantic, or into sea-lochs, sounds, etc., closely connected therewith. As every part is so near some coast-line, the rainfall needs only short though steep paths to reach the sea. No large rivers draining extensive outside areas pass through, and the streams, though liable to heavy spates, are generally shallow. Perhaps the most important streams are the following : Abhuinn Camas Fhionnairidh, flowing into Loch Scavaig, Skye ; Allt Glen Udalain, flowing into Loch Alsh from the north ; Glenmore River, Amhainn a' Ghlinne Bhig and Amhainn Ghuserein, all three discharging into the Sound of Sleat from the west.

The population is chiefly collected along the sea-board, but is very sparse and has been decreasing for many years past. In 1881 the united population in the civil parishes of Glenelg, Glenshiel, Loch Alsh, Sleat and Strath—which include between them nearly all the area being described, together with considerable tracts outside it—amounted to 9278, while in 1901 it had dropped to 7311.‡ In the parish of Glenelg, with a total area of 134,788 acres, the area for each inhabitant amounted in 1901 to 93·4 acres. C. T. C.

Broadford, in the north of Strath, contains the parish church, and may be said to include a scattered population that extends some distance eastwards in the hamlets of Harrabol, Sgiabain, Skulamus and Upper and Lower Breakish.

Fishing, the cultivation of strips of land, and the tending of sheep and cattle, form the chief occupations of the inhabitants. Lime-burning is also carried on at Broadford.

In Strathaird the population is centred in the village of Elgol and the hamlets of Kilmarie and Keppoch.§ In the south of Strath it is almost confined to the villages of Torran, at the head of Loch Slapin, and Heast near the coast of Loch Eishort. The village of Sconser extends along the south coast of Loch Sligachan.

H. B. W., C. B. W.

Tabular Statement of Formations.

The first part of the following list shows the chief rocks, etc., included in the map, of which the relative ages are known. The

* Calculated from data given in "British Rainfall" (edited by H. S. Wallis and Dr. H. R. Mill).

† Map compiled from averages of 25 years, by Dr. Alex. Buchan for the Royal Scottish Geographical Society's Atlas of Scotland.

‡ This information has been derived from the records of the decennial Census Returns for 1881 and 1901. For other particulars about the population and its occupations reference may be made to Chapter XV.

§ "Capach" on the one-inch map. This is a wrong spelling. It is spelt Keppoch on the new six-inch map.

rocks in the second part are all older than these, but there is doubt about the relative ages of some of them :—

I.

Pleistocene and Recent.	Peat.	
	River Gravels and Alluvia.	
	Raised Beaches.	
	Fluvio-glacial Sands and Gravels.	
	Morainic Drift. Irregular deposits of stony rubble, etc. Boulder Clay.	
Tertiary Igneous Rocks.	*c.* Minor Intrusions : numerous groups of dykes with some intrusive sills and sheets.	
	b. Plutonic Intrusions. 2. Granites, including granophyres.	
	b. Plutonic Intrusions. 1. Gabbros.	
	a. Volcanic Rocks. 2. Basaltic lavas.	
	a. Volcanic Rocks. 1. Volcanic agglomerates.	
Cretaceous.	Upper Cretaceous (Cenomanian).	Cherty sandstone, marine blue limestone and calcareous grit : thickness exposed about 18 ft.
Jurassic. Corallian and Oxfordian.	Corallian and Upper Oxford Clay (*Cordatus* zone).	Micaceous shales passing down into calcareous sandstones, pebbly at the base : thickness probably about 300 ft.
	Kellaways Rock (*Calloviensis* zone) : remnants not seen in place.	[Calcareous sandstone].
	Great Estuarine Series (Loch Staffin Beds).	Chiefly laminated shales with *Paludina* Limestones, *Ostrea-hebridica* Beds, *Cyrena* Limestones in upper half : thickness about 400 ft.
	Inferior Oolite Series up to, and including, lower part of *Parkinsoni* zone.	Calcareous sandstones and grits with a bed of shale near top. Thickness not much less than 800 ft. in Strathaird.
	Lias. Upper Lias (*Communis* and *Serpentinus* zones).	Chiefly black shales : thickness about 20 ft. in Strathaird.
	Lias. Middle Lias (Scalpa Series) (*Spinatus* and *Margaritatus* zones).	Calcareous sandstones.
	Lias. Lower Lias. Pabba Shales (*Capricornus, Jamesoni, Armatus*, and *Raricostatus* zones, locally represented).	Micaceous shales and shaly sandstones. Thickness up to 700 ft.
	Lias. Lower Lias. Broadford Beds (*Obtusus* zone in part represented locally ; *Semicostatus* and *Bucklandi* zones, main portions ; *Angulatus* and *Planorbis* zones probably represented in point of time).	Chiefly sandstones and limestones. Some beds conglomeratic.

Triassic or New Red Series.	Passage-Beds (Rhaetic?)	Greenish and bluish calcareous sandstones and black shales.
	Trias.	Red and white conglomerates and sandstones, with red and green marls, the conglomerates sometimes becoming calcareous.
Lower Old Red Sandstone?	Intrusive igneous rocks of the Glenelg-Ratagain complex — chiefly granite, diorite and syenite — together with sheets and dykes of quartz-felsite, porphyrite, mica-trap, etc.	
Middle and Upper Cambrian.	Durness Dolomite and Limestone.	Ben Suardal zone.
		Strath Suardal and Beinn an Dubhaich zone.
		Sangomore zone.
		Sailmohr zone.
		Eileandubh zone.
		Ghrudaidh zone.
Lower Cambrian.	Serpulite Grit.	
	Fucoid Beds, with "*Olenellus*" zone.	
	Durness Quartzite.	"Pipe-rock," about 220 ft.
		Lower or False-bedded Quartzite, about 330 ft.
Torridonian.	Applecross Group: about 5000 ft. seen without reaching the top.	
	Diabaig Group: total thickness may be as much as 7000 ft. without reaching the base.	Kinloch Beds.
		Beinn na Seamraig Grits.
		Loch na Dal Shale Series.
		Epidotic grits and conglomerates.

II.

Pegmatites and granite-gneisses (rare) common to the Moine rocks and the Lewisian Gneiss series.

Hornblende-chlorite-rock, partly schistose, representing an intrusion in the Moine series.

Moine Series.	Psammitic, pelitic and semipelitic schists and gneisses of various types, including siliceous flagstones and thin seams of garnet-actinolite-zoisite-quartz-rock. Boulder-bed or conglomerate-schist at the base in one locality.

Lewisian Gneiss Series.*	Foliated basic and ultrabasic rocks showing evidence of intrusion.
	Pegmatitic lenticles and seams, for the most part thoroughly granulitised and foliated.†
	Eclogites and allied hornblende-schists, sometimes graphitic.
	Serpentine and other ultrabasic rocks.
	Felspathic gneisses poor in ferromagnesian constituents.
	Thinly banded hornblendic gneisses.
	Granulitic biotite-gneiss.
	Biotite-schist, garnetiferous biotite-kyanite-gneiss, granulitic garnetiferous biotite-gneiss and some allied rocks; sometimes graphitic.
	Limestones, calc-silicate bands and calcareous gneisses; sometimes graphitic.

* The order in which the different rocks in this series are placed does not necessarily imply the order of age, nor the order in which they are subsequently described.

† These are not shown in the published map, but are partially described with the rocks in which they occur.

Distribution of Formations and Tectonic Structure.

In respect to geological stratigraphy the land space can be divided into three areas which almost coincide with the geographical divisions already alluded to in the fifth paragraph of this chapter. On the west is the area which consists mainly of Tertiary igneous rocks, including big intrusive masses of granophyre and gabbro (of which last Blath-bheinn is composed). The central band is mainly composed of Torridonian, Cambrian and Jurassic rocks. The south-eastern area, including about a third part of the mainland north of Loch Alsh and nearly all the mainland south of that loch, lies on the south-east side of a most important structural line—that of the post-Cambrian Moine thrust, which enters the map near Achmore, near the north-east corner, and strikes thence across the map in a south-west direction, past Kyle Rhea, Camas a'Mhuilt and Loch Meodal, to the southern margin. The rocks in this area are chiefly composed of gneisses and schists, which are divisible into two great groups, one of which has probably been formed from sedimentary rocks and belongs to the Moine series—the series which also in Sutherland and northern Ross-shire forms a large part of the area on the south-east side of the Moine thrust. The other group includes a considerable proportion of gneisses and schists .which are probably of igneous origin, and greatly resemble rocks which in districts further north are referred to the Lewisian Gneiss series, being clearly of pre-Torridon age.

H. B. W., C. T. C., A. H., C. B. W.

During the last ten or twelve years, facts have been gradually accumulated by Dr. Peach and Messrs. Clough, Hinxman, Crampton, Anderson and Carruthers, which render it probable that the Moine series is younger than the Lewisian Gneiss series,* though the rocks of both have many characters in common, having passed together through a period of sharp isoclinal folding and intense metamorphism. The relation of this period of folding and metamorphism to that of the post-Cambrian folds and thrusts, of which last, many, in addition to the Moine thrust, are excellently seen in the central area, will be discussed subsequently,† but it may be said now that the axial planes of most of both sets of folds strike in nearly the same direction, between north-east and north-north-east, and incline south-east, or south-south-east. Some of the folds which affect the schists and gneisses south-east of the Moine thrust are shown in the horizontal section (Fig. 1), which has been drawn in a general east-south-east direction from Rudha a' Chamais Bhàin over Mam an Fhuarain, Beinn a' Chapuill, Beinn Sgriol and Beinn nan Caorach, to the eastern margin of the map. The strike and direction of dip of the banding and the foliation are twisted systematically near the top of Beinn a' Chapuill, but the change is not indicated very well in the Figure, as the direction of the line of section is also changed considerably at this locality. The twist is of such a nature that the under limbs of isoclines dipping gently east on the west side of the hill become upper limbs of isoclines dipping more steeply south on the

* *Summary of Progress* for 1897, p. 36; 1898, pp. 8, 9; 1899, p. 17; 1904, pp. 75–78.
† See Chapter III. Introduction.

south-east side. The twist is probably connected with wrench-movements along the faults—the Ben Sgriol faults—shown in the section near Loch Bealach na h-Oidhche.

Some of the marks of metamorphism which the Lewisian Gneiss and the Moine rocks exhibit in common are summarised below :—

1. Isoclinal folding and foliation.
2. General granulitisation of the quartzo-felspathic rocks.
3. Development of actinolite needles spearing across the banding or bedding in certain rocks.
4. Formation of scattered spots of new felspar—frequently microcline or orthoclase.
5. Introduction of newer pegmatites, in numberless thin lenticular streaks and spots, and also in broad dyke-like bands.

It cannot, however, be said that all the folds in the Lewisian Gneiss rocks affect the Moine rocks also. It seems probable, indeed, though this has not been proved in this district, that the former rocks were sharply folded, as well as greatly altered, before the representatives of the latter were deposited. It is supposed that during the period in which the Moine rocks were altered, most of those parts of the Lewisian Gneiss which admitted of further alteration were again altered, and that at the same time the general strike was twisted into the present direction.

Certain parts, however, for example the massive eclogites, are quite free from shearing, though they have, perhaps, passed through more than one period of sharp folding. In this respect, as in some others, they are comparable to the pyroxene-granulites and garnet-amphibolites of the Lewisian Gneiss series in the district of

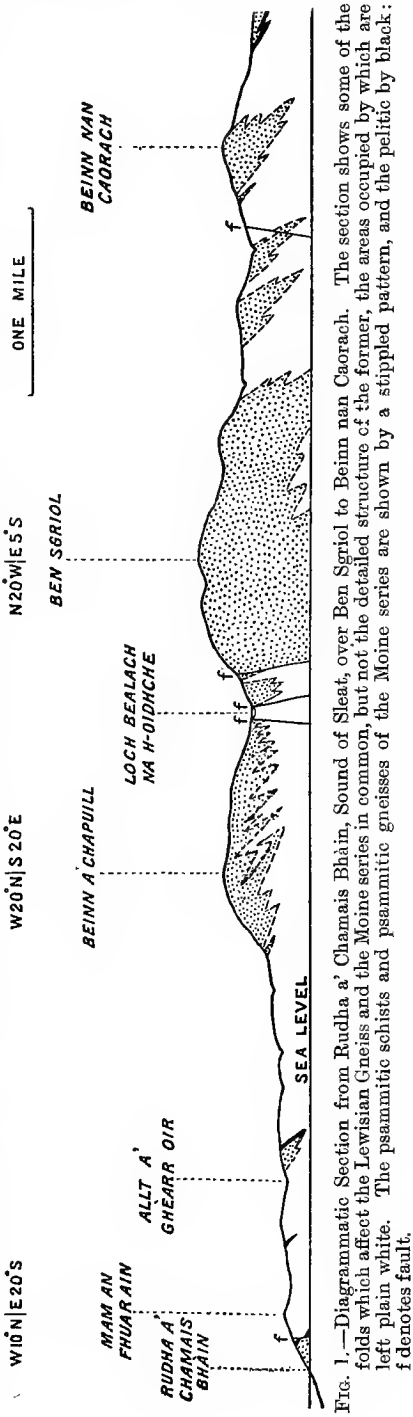


FIG. 1.—Diagrammatic Section from Rudha a' Chamais Bhàin, Sound of Sleat, over Ben Sgriol to Beinn nan Caorach. The section shows some of the folds which affect the Lewisian Gneiss and the Moine series in common, but not the detailed structure of the former, the areas occupied by which are left plain white. The psammitic schists and psammitic gneisses of the Moine series are shown by a stippled pattern, and the pelitic by black: f denotes fault.

Scourie, one-inch map 107, which have been much less affected by the pre-Torridon thrusts and folds than most of the neighbouring thin banded gneisses: they are, indeed, repeatedly found in the form of big *augen* surrounded by shear lines, though the interiors often still retain a thoroughly massive structure.

It has long been thought by Dr. Peach and some other geologists that the Moine rocks are the altered representatives of certain of the Torridonian rocks,* but this is a matter which is still *sub judice*. Various important facts which count for and against this supposition are enumerated at the commencement of Chapter III.

All the Torridonian and Cambrian rocks are probably in a thrust condition, lying on some big thrust—perhaps the Kishorn thrust—the outcrop of which has presumably been obliterated in this area by the Tertiary igneous masses. A striking peculiarity of many of the thrusts of this region is their folded condition. It is to be noted, however, that in the district of Strath, where one of the thrusts—the Ben Suardal thrust—has been bent into a anticline, the Mesozoic strata have also been folded in a similar fashion, into an anticline in which the west limit is the steepest, and it is clear that a great part of the fold must have been developed in post-Liassic times. It is certain that long before these Mesozoic strata were deposited, the Torridonian and Cambrian rocks had acquired a north-east or north-north-east strike, and had been folded and thrust; but in a subsequent age crustal movements were again renewed, with less intensity, on nearly the same lines as before.

Within the gneisses and schists near the eastern margin of the map comes the western portion of the Glenelg-Ràtagain igneous complex, which is composed chiefly of granite, syenite and diorite with subordinate masses of pyroxenite and hornblendite, which were consolidated before the more acid rocks.† It is associated with many dykes, most of them classed as porphyrite, and is perhaps of Lower Old Red Sandstone age, as it has close petrological affinities with the plutonic masses of Criffel and Ballachulish. The general metamorphism of the Lewisian Gneiss and of the Moine series was completed, and much as it is now, before these igneous rocks were introduced.

C. T. C.

The main expanse of Triassic and Liassic rocks stretches completely across Strath, the middle members of the series having a northward prolongation through the island of Pabba into the south-east of Scalpa, and the highest reaching south-westward to the east coast of Strathaird; while an outlying tract of the Lower Lias recurs in Srath Beag at the head of Loch Slapin.

The principal area of the younger Secondary rocks, partly concealed by Tertiary basalts, and almost continuous with the Lias of

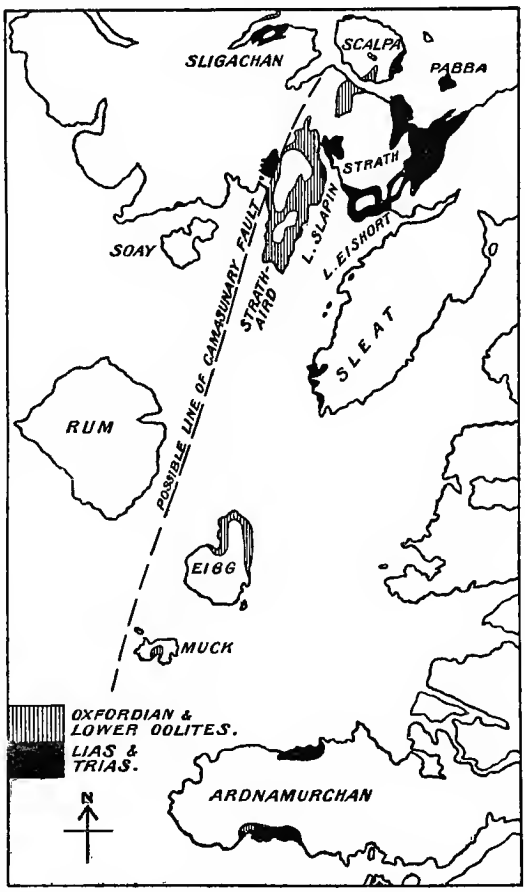
* That this was probable was stated by Dr. Peach in 1892, after his examination of the area south of Loch Carron. "Annual Report of the Geological Survey" for 1892, p. 262.

† Cf. J. R. Dakyns and J. J. H. Teall, "On the Plutonic Rocks of Garabal Hill and Meall Breac," *Quart. Journ. Geol. Soc.*, 1892, vol. xlviii. p. 107.

Srath Beag, forms the promontory of Strathaird, and exhibits a sequence ranging from the top of the Middle Lias to the Oxfordian and Corallian, overlain by the Upper Cretaceous, which, however, is little seen. Further north at Strollamus the same sequence, much metamorphosed, is represented from the Inferior Oolite upward, and the higher part of it continues into the South of Scalpa.

On the west side of Strathaird the Lower Lias is thrown up again; and some distance northward Triassic and Lower Liassic strata descend from the slope of Glamaig to the south shore of Loch Sligachan, a narrow fringe of Inferior Oolite being found on the further side of that loch. The Trias, of which a small patch remains in the north-west corner of Scalpa, reappears in the south of Raasay, where it is followed by the Lower Lias.

The detailed determination of the Secondary rocks in Strathaird, at Strollamus, and in the south of Scalpa, brings out in a striking manner the completeness of their sequence and the uniformity of their distribution along a northerly strike from Ardnamurchan to Strath and Scalpa. A regular upward succession to the west is but slightly masked in the north by minor undulations and disturbances. The lower portion of the sequence crops out, wholly or in part, in Ardnamurchan, in Sleat, and in Strath and the east of Scalpa; while the upper strikes from the west of Ardnamurchan by Muck, Eigg, Strathaird and Strollamus to the south of Scalpa (see sketch-map, Fig. 2). Further west the repetition of the succession from its base westward and northward is due to the intervention of a great fault (see Chap. XIII.).



Scale, 1 inch = 10 miles.

FIG. 2.—Sketch Map to illustrate the Distribution of the Secondary Rocks in the South of Skye and its Neighbourhood.

The representation of the Secondary Rocks in Ardnamurchan is taken from Prof. Judd's map (*Quart. Journ. Geol. Soc.*, vol. xxxiv. pl. xxxi.).

An unconformability marks the junction of the Upper Cretaceous with the Jurassic. While some part of the Corallian clays is certainly included in the Oxfordian, we have no reason to believe that any Kimeridgian or higher Jurassic strata occur; and the Lower Cretaceous is absent. There is a strong presumption that earth-movements, resulting in the production of great north-north-easterly faults with easterly downthrow, took place in the interval before the formation of the Upper Cretaceous (see Chap. XIII.).

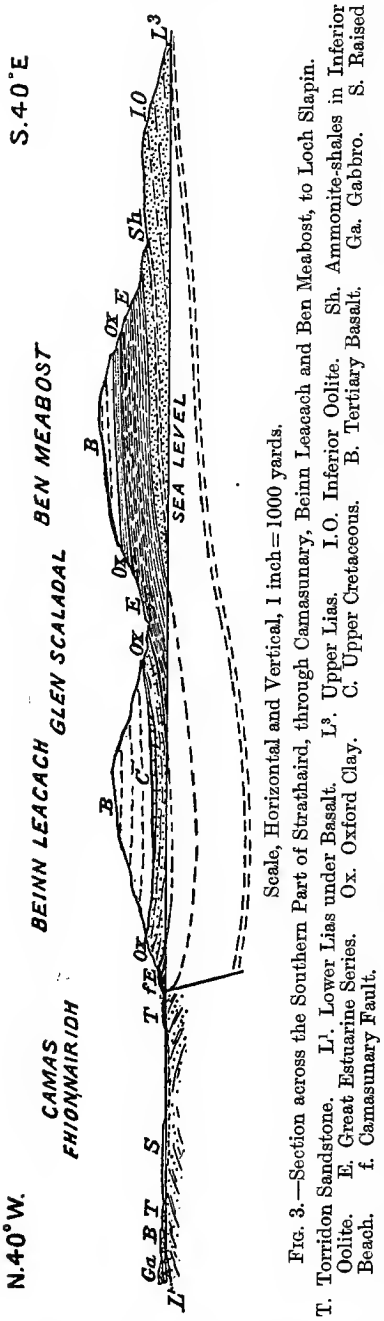


Fig. 3.—Section across the Southern Part of Strathaird, through Camasunary, Beinn Leacach and Ben Meabost, to Loch Slapin.
Scale, Horizontal and Vertical, 1 inch = 1000 yards.
T. Torridon Sandstone. L¹. Lower Lias under Basalt. L³. Upper Lias. I.O. Inferior Oolite. Sh. Ammonite-shales in Inferior Oolite. E. Great Estuarine Series. Ox. Oxford Clay. C. Upper Cretaceous. B. Tertiary Basalt. Ga. Gabbro. S. Raised Beach. f. Camasunary Fault.

On the other hand, except for the apparent absence of nearly all the lower Oxfordian, the succession of the Triassic and Jurassic strata of the district is unbroken, though within the period covered by their deposition marked changes took place in the conditions of sedimentation.

Mr. Harker has shown that the mountain-district of Skye was an area of crust movement long before the Tertiary episode of igneous activity,* and we perhaps see the effects of this in the Secondary rocks. Thus there is a decided tendency for the lowest calcareous groups of the Lower Lias to thin out as they approach the mountain region. At Loch Sligachan this seems to take place without affecting the Trias and the Passage-beds.

Mr. Harker notes also that the anticlinal ridge of Beinn an Dubhaich and Ben Suardal in the west of Strath was initiated before Mesozoic times.† And we find, where the Secondary rocks flank this uplift on the south, a progressive overlap of their lowest beds until limestones containing *Arnioceras* of the *Semicostatus* zone come to rest directly upon the Cambrian limestone on the coast of Loch Slapin.

It may be not without significance too that the Inferior Oolite

* See "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, pp. 413–414.
† *Op. cit.*, p. 414.

shows a great increase both of thickness and of sandy material close to and within this mountain region.

In Strathaird the Tertiary volcanic rocks slightly overstep the highest Secondary strata northward. C. B. W.

The general sequence of strata from the New Red rocks near Lusa and Breakish east of Broadford, through the stone-beds of the Lower Lias to the shales of Pabba and the Middle Lias on the south-east of Scalpa is well marked. Near Broadford the beds have been subjected to a good deal of disturbance, and the uplifted strata towards Heast present evidence of numerous faults. H. B. W.

The synclinal crescent, in which the Secondary rocks sweep round from Broadford Bay to the coasts of Loch Eishort and Loch Slapin, opens out south-westward in the angle between these lochs, so that southerly and south-westerly dips on the shore of Loch Slapin veer to a westerly or north-westerly inclination on Loch Eishort.

The syncline of Strath appears to be confluent with a shallow synclinal basin occupying the whole promontory of Strathaird. The axis of this basin trends S.S.W. from Strath Mòr through Beinn Leacach (see Fig. 3), and the fold, expanding and sinking slightly southward, has a lower dip in its eastern than in its western limb. The small arch in the Upper Lias at Faoilean may be influenced by the anticline of Beinn an Dubhaich (see Chap. V.).

A narrow anticline running south-westward through the east flanks of Belig, Sgurr nan Each, and Blath-bheinn to Camas Fhionnairidh, separates the Strathaird basin from the eastern syncline of the gabbro district in Blath-bheinn and its neighbourhood.

The Mesozoic strata have a high dip eastward and south-eastward off the granophyre of Glas Bheinn Bheag (see Fig. 12), and the structure continues into the south of Scalpa. The relation of this structure to that of Strathaird is clear. The intrusion of the intervening granite mass, of which Beinn na Crò is the most conspicuous elevation, has reversed the westerly dip of the north-east side of Strathaird, and induced a steep eastward inclination.* Seen from the top of Belig this is readily apparent, for the view takes in the westward inclination of the Inferior Oolite sandstones along the coast of Strathaird, the mass of Beinn na Crô, and beyond in the distance the eastward-dipping escarpment of the same sandstones on the crest of Glas Bheinn Bheag.

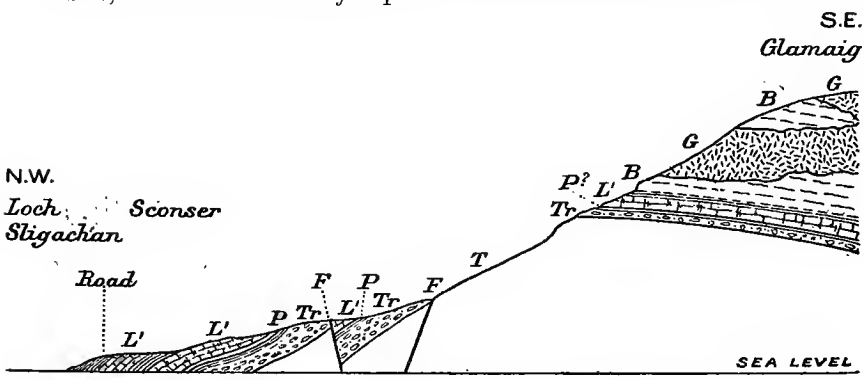
The Secondary rocks dip steeply north-westward and northward off the Torridon Sandstone on the lower flank of Glamaig in a long slope.† This dip-slope forms the northern limb of an anticline trending slightly north of east (see Fig. 4).‡ At the west end of the Jurassic tract, before these rocks pass westward and southward under the lavas, their inclination changes through west to south, and the Liassic shales plunge down under the basalt-escarpment at Leathad Dubh. The axis of the fold runs but little below this escarpment, beneath which eastward successively lower beds dip in turn, until a northerly fault throws the Lias down on the east against Torridon Sandstone.

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 146.

† See J. Bryce, "On the Jurassic Rocks of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. pp. 318 and 321, and plate xi. fig. 2.

‡ *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 146.

Beyond this fault the saddle diverges further from the scarp of the lavas. The lowest Mesozoic beds still bend over southward at a high angle, but quickly turn up again synclinally before passing under the basalt, now with northerly dip.



Scale, Horizontal and Vertical, 3 inches = 1000 yards.

FIG. 4.—Section from Glamaig to Loch Sligachan, cutting the Road 250 yards N.E. of the Second Milestone from Sligachan.

T. Torridon Sandstone. Tr. Trias. P. Passage-beds. L^1. Lower Lias.
B. Tertiary Basalt. G. Granophyre. F. Fault.

The strike shows that a fault intervenes, under the loch, between the Lower Lias and the Inferior Oolite, as Bryce suggested.*

Although in the neighbourhood of the large intrusive masses the Secondary rocks are often highly metamorphosed, as in the north of Strathaird, yet at a distance from these igneous masses they are little if at all altered, except where in contact with dykes and sills. Throughout the greater part of Strathaird and the southern part of Strath this alteration is very slight, though the belief seems to have gained acceptance that the beds in those localities have suffered such change as to obscure the fossil-evidence of their age. Still there has perhaps been even there some slight induration, for we seldom or never find argillaceous strata in such a soft condition as, for instance, the Oxford Clay in England. C. B. W.

The Tertiary igneous rocks of Skye, having been recently described in a separate Memoir,† will not be discussed at length in the present volume. By correlation with the corresponding rocks of Mull and Antrim, it is ascertained that the basaltic lavas are of Eocene age, but the succession of intrusive rocks which followed these may have trenched upon some of the succeeding divisions of Tertiary time. The higher ground of the Strathaird peninsula is composed of an outlying portion of the great basaltic plateau which makes up all the northern and western parts of Skye, and which just enters this map at its north-west corner, forming the terraced hill Ben Lee to the

* " On the Jurassic Rocks of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. pp. 319 and 321.

† " The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, by Alfred Harker.

north of Loch Sligachan. The granite and granophyre of the Red Hills occupy, however, a much larger area in this map than the plateau-basalts, and extend from Ben na Caillich, near Broadford, to the western margin of the sheet. On the south side of the Red Hills lies the Blath-bheinn or Blaven range, which presents a much bolder relief than they, and is composed of an outlying portion of the Cuillin gabbro.

Relation of Scenery to Geological Structure.

The varied geological constitution of the country included in this map has given rise to a corresponding variety in the landscape. In the western part of the sheet, where the Tertiary igneous rocks are developed in force, this relation of physical features to geological and lithological nature is especially well illustrated. The flat-topped hills with terraced slopes in the northern part of the Strathaird peninsula and to the north of Loch Sligachan are examples of the plateau type of scenery resulting from the strong dolerite sills which alternate with the basaltic lavas. In the Blath-bheinn (Blaven) range and in Sgùrr na Stri we see the bold outlines and broken summit-ridges which are characteristic of the gabbro mountains of Skye. In contrast with these are the smooth flowing outlines of the Red Hills, composed of granite. Of these the isolated group of Beinn na Caillich and the ridge of Beinn an Dubhaich indicate the shapes of the distinct granitic masses which give rise to them ; while the continuous tract of the main Red Hills has been large enough to have an internal drainage-system, and is carved out into a number of distinct hills. A. H.

Previous Geological Literature.

Comparatively few authors have dealt with the older rocks of this district,* but Dr. Macculloch † described different varieties of schist and gneiss in the south-eastern peninsula of Skye at considerable length, and referred occasionally to the neighbouring parts of the mainland. In his "New Geological Map of Scotland," bearing date 1832, he took together under the name of gneiss the two sets of rocks which we now place separately, one with the Moine series and the other with the Lewisian Gneiss : he drew the boundary of the gneiss correctly, and showed, at Glenelg and for some miles further north-east, the "primary limestone" in the gneiss. In common with many of his contemporaries he appears to have been largely influenced by Werner's theories, and to have considered that much of the gneiss was deposited in a way more or less comparable with modern sediments, but in a thermal ocean under peculiar nascent conditions of the planet. A great part of the Torridonian formation he calls Old Red Sandstone, but colours another part as mica-slate. Sir R. I. Murchison in the map accompanying his account of "The Succession of the Older Rocks in the Northernmost Counties of Scotland," ‡ colours the Torridonian rocks as Cambrian, and in a subsequent joint paper with

* A full Bibliography relating to all the rocks is given in the Appendix.
† "A Description of the Western Islands of Scotland," 1819, vol. i.
‡ *Quart. Journ. Geol. Soc.*, 1859, vol. xv. p. 353.

Sir A. Geikie * the rocks on the south side of Loch Duich, including bands of limestone and the micaceous or slaty flagstones "which pass into gneiss," are referred to, and a horizontal section is described (extending from Loch Hourn by Loch Quoich to the Caledonian Canal), in which attention is called to the reduplication by folding of gneiss, mica-schist and micaceous quartz-rock.

The Jurassic rocks of Skye, Scalpa, Pabba and Raasay have attracted much attention from the days of Macculloch in 1819 and Murchison in 1827. To Sir Archibald Geikie, thirty years later, we owe the first detailed account of the Lias of Strath, and he was followed in 1873 by Dr. James Bryce and Professor Ralph Tate, who dealt more particularly with the Jurassic rocks of Raasay and the borders of Loch Sligachan, and added much to our knowledge of the fossils. Five years later Professor J. W. Judd gave descriptions of all the Jurassic rocks then recognised in the Inner Hebrides, dealing fully with the history of the subject, with the correlation of the various subdivisions, and largely increasing our information respecting the distribution of the strata and their organic remains. The district of Strathaird has received less attention than other tracts, no doubt from the fact that it is less accessible; and the results of the recent survey in that region have added largely to our knowledge, and have at the same time rendered some modifications necessary in the conclusions briefly indicated by Professor Judd with regard to the age of certain strata. The titles of the papers are recorded in the Bibliographical Appendix, and further references will be made in the text to the labours of the several authors to whom we have been indebted.

The literature of the Tertiary igneous rocks of Skye is somewhat voluminous. It will be sufficient in this place to mention the names of the more important contributors. Setting aside some scattered observations by Jameson, the first systematic description is that of Macculloch, whose great work was published in 1819. Boué (1820) and von Oeynhausen and von Dechen (1829) did not make any very considerable additions to the knowledge of the district; and, as regards the actual relations of the igneous rocks, little advance was made until Sir Archibald Geikie and Professor Judd independently addressed themselves to the study of the Tertiary igneous region of Britain, of which Skye is a part. Exception should be made for a valuable paper by J. D. Forbes (1845), in which the laccolitic nature of the principal gabbro mass of Skye was clearly recognised. Sir Archibald Geikie's first paper, dealing with part of the area within this sheet of the map, was presented in 1857.

Professor Zirkel, in 1871, was the first to apply the modern methods of petrography to the igneous rocks of this district; and this side of the subject has, in later years, been prosecuted in some important memoirs by Professor Judd. In 1874 the last-named geologist put forward a general view of the Tertiary igneous rocks of the British area, supposing the existence of several great volcanoes, to which the whole suite of rocks stand related; and one of these volcanoes was placed on the site of the Skye mountains. Sir Archibald Geikie's

* "On the Altered Rocks of the Western Islands of Scotland, and in the North-Western and Central Highlands," *Quart. Journ. Geol. Soc.*, 1861, vol. xvii. p. 171.

researches led him to different conclusions concerning the relative ages and mutual relations of the various associated rocks. In his view the volcanic rocks have emanated from fissure-eruptions, and the plutonic intrusions are of later date. He has embodied in his "Ancient Volcanoes of Great Britain" (1897) the results of a long series of investigations dealing with this among other districts.

H. B. W., C. T. C., A. H.

CHAPTER II.

LEWISIAN GNEISS SERIES.

Section I.—Areas North-West of the Moine Thrust.

South of Loch Alsh.

The rocks included in this section occupy but small areas, being confined to a thin stripe a little east of Kyle Rhea, Dun Ruaige (west side of the Sound of Sleat), thin bands near Tarskavaig and between there and the southern margin of the map, and a little outlier (near Tarskavaig Bay), which was no doubt formerly connected with one of these bands.

The thin stripe mapped as Lewisian Gneiss a little east of Kyle Rhea is probably never more than 100 yds. broad. It consists of a pale buff flaggy felstone-like mylonite, generally dipping east at 30° or 40°, and characterised by prominent stretching lines running nearly parallel to the direction of dip. Neither the field sections nor microscopic examination (8122) conclusively settle the nature of the parent rock. The stripe is probably separated by a thrust from the sheared Torridonian sandy shales on the west, and on the east it is clearly faulted against a siliceous Moine schist.

The patch at Dun Ruaige consists for the most part of a compact fine flaggy greenish grey rock with lustrous foliation planes generally dipping E.S.E. The indications of stretching are much stronger than in the adjacent Torridonian beds, from which it is probably separated by a thrust, and the original character cannot be determined; there is room to doubt even whether the rock belongs to the Lewisian Gneiss series. Under the microscope (5411) some of the folia are seen to consist in the main of a microcrystalline mosaic of colourless minerals, while others contain minute scales of mica, chlorite and grains of carbonate (rare).

The bands near and south of Tarskavaig form an almost continuous but sometimes very thin stripe on the inner side of the outcrop of a synclinally folded thrust—the Tarskavaig thrust—on which they have been carried forward together with a much larger mass of Tarskavaig Moine rocks. The best exposures are on the coast two-thirds of a mile E.N.E. of the foot of Loch Nigheann Fhionnlaidh and on the hillsides between Achnacloich and the south margin of the map. In the first locality a phyllite of the Tarskavaig Moine series rests directly on an unctuous green schist belonging to the Lewisian Gneiss series; the line of junction is slightly waved but nearly parallel to the bedding of the phyllite, and the foliations in the two rocks are parallel to one another and slightly steeper than the bedding in the phyllite.

One of the commonest types of rock in these Tarskavaig bands is a soft flaggy yellowish green schist with red felspathic spots and streaks. In certain localities, as for instance 350 yds. south-east of Sgùrr Breac, this green schist contains small pieces of black hornblende, generally about the size of a pea and somewhat rare, which probably represent sheared portions of some basic rocks rich in hornblende, while the redder portions may represent more felspathic bands in the same rocks, or perhaps in some cases sheared pegmatites.

In Gillean Burn, a little more than two-thirds of a mile E.S.E. of Gillean, an unctuous grey schist encloses more massive *augen*, some as much as a foot broad, which are chiefly composed of pyroxenite (7336),* and higher up the burn this schist is associated with a massive yellowish rock (7337), which Dr. Teall states may be a serpentinous modification of pyroxenite. The schist or this massive rock can be traced for considerable distances on both sides of the burn, the massive rock being particularly well seen in the area between a mile E.N.E. and 300 yds. east of Sgùrr Breac, and again 250 yds. south-east of the same hill, in a thin band close to the Tarskavaig Moine rocks. In one locality it seems to transgress slightly the foliation of a more acid band, and possibly it represents an intrusion. C. T. C.

North of Loch Alsh.

Between Srath Ascaig in the north-east corner of the map and Kirkton of Lochalsh, there is a belt of Lewisian gneiss, from one to two miles broad, which has been affected by the great post-Cambrian displacements west of the Moine thrust.

In the north-west part of the area, between Fernaig and Gleannan Dorch, a slice of the overturned Archæan floor is superimposed on the inverted Torridon Sandstone. Close to the boundary line where there has been great differential movement of the constituents, the Lewisian rocks consist of granulitic biotite-gneiss, the foliation being more or less parallel with the strike of the underlying epidotic grits and shales. Eastwards, however, there are masses of grey biotite-gneiss with bands of hornblende-schist that still possess traces of the original foliation. The most striking feature of this displaced mass is the occurrence in it of a thick sill of hornblende-schist, that closely resembles the Ben Lair intrusive sheet north of Loch Maree. It crosses Srath Ascaig at Achmore and has been traced south-west by Allt a Mhuillin towards the head of Loch nan Gillean. Beyond the limits of the map, W.N.W. of Stromeferry, thin bands of garnetiferous mica-schist and rusty brown mica-schist are associated with the northern prolongation of this sill.

Eastwards and southwards from the massive sill of hornblende-schist towards Braeintra and Beinn Raimh bands of highly sheared platy gneiss and hornblende-schist, indicating lines or zones of movement, are associated with grey biotite-gneiss in which the original structures are not wholly destroyed. The fissile platy rocks are well displayed on the crest of Beinn Raimh where the foliation planes dip to the east or E.S.E.

* The numbers attached to rock slices and specimens indicate their labelled numbers in the collection of the Geological Survey of Scotland.

Southwards by Kirkton Hill to Kirkton of Lochalsh, there is a broad belt of pink and grey sheared biotite-gneiss with well-marked flaser structure and containing lenticular bands of hornblende-schist. In places the original structures are still apparent. On the south slope of Kirkton Hill the strike of the foliation of the gneiss is N.N.W. and S.S.E., but as a rule it harmonises with the strike of the post-Cambrian thrusts. In a small stream about a quarter of a mile W.N.W. of Auchtertyre farm house, a thin lenticle of sheared marble appears in the midst of the deformed gneiss, and has been traced for a distance of 200 yds.

The extreme deformation of the Lewisian rocks produced by the post-Cambrian movements is clearly shown along the line of the outcrop of the Balmacara thrust which has been traced from the shore south of Ard Hill to Gleannan Dorch (see map). In certain places, as for instance on the shore of Loch Alsh and on the wooded slopes north-west and north-east of Balmacara Burn, it is difficult to determine where the line of disruption should be drawn. The rocks consist of grey and rusty brown platy schists with lustrous surfaces and friable green chloritic schists which may probably represent acid and basic portions of the Lewisian Gneiss. The new divisional planes are more or less parallel with the plane of the Balmacara thrust and are generally inclined to the E.S.E. B. N. P., J. H.

Section II.—Areas South-East of the Moine Thrust.

South of Loch Alsh and Loch Long.

INTRODUCTION.

About half of the area between Loch Alsh and Loch Duich on the one side and Loch Hourn on the other is composed of rocks of the Lewisian Gneiss series, in the form of bands never more than two miles broad, which generally strike N.N.E. and are separated from one another by other bands composed of Moine rocks. In the Island of Skye a considerable area is found on the same side of the Moine thrust, between Camas a' Mhuilt and Ostaig, and attains a breadth of a mile and a half or more. A small area is found between Loch Long and Loch Duich, and another, of still less dimensions, on the south side of the mouth of Loch Hourn at Rudh' Ard Slisneach.

In the landscape these rocks generally make lower, greener and less rocky features than the associated Moine rocks. In certain cliffs, as for instance the west face of Beinn a' Chapuill, Glenelg (*see* Frontispiece), where rocks of the Lewisian Gneiss series occur in thin stripes between thicker masses of siliceous Moine schist, the former make ledges, along which it is possible to scramble, with almost perpendicular walls above and below. As a rule, also, they show a greater variety of colour than the Moine rocks, pale pink and green tints being almost as common as grey and repeatedly mixed with it in thin stripes.

The general dip of the banding or first foliation is E.S.E., but this merely represents the dip of limbs of isoclinal folds, examples of which are seen in nearly every good exposure.

Perhaps the most striking local peculiarity of the series is the widespread occurrence of beds of limestone,* and of great bands of garnetiferous biotite-kyanite-gneiss, together with certain other schists or gneisses which closely resemble altered sediments. These rocks are intimately mixed, as a rule in sub-parallel bands and lenticles, with other schists and gneisses which have probably been derived from igneous rocks, but besides these two classes of rocks—the paragneisses and the orthogneisses of Rosenbusch †—there are others which cannot be referred with confidence to either class. No systematic separation of the two classes has therefore been made. There is no evidence that the altered sediments, or paragneisses, are unconformable to and younger than the rocks of igneous origin, nor are the former ever distinctly transgressed by the latter. The working hypothesis which most commends itself to the writer is that the series represents a complex in which the oldest rocks are of sedimentary origin and have been injected and greatly altered by a variety of igneous rocks, intruded under peculiar conditions and considerable pressure. In a peculiar kyanite-garnet rock (9339) near Tigh Dhruideig, Loch Hourn, Dr. Teall has detected a mineral which he thinks may be staurolite, one of the most familiar products of contact alteration. The difficulty of distinguishing the rocks supposed to be of sedimentary origin must have been largely increased by later processes of metamorphism and folding—perhaps belonging to more than one period—but the limestones have not been susceptible to so much change as most of the other rocks, so that their original character can be more readily inferred.‡

In certain areas, red or white bands, or thin subparallel streaks and lenticles, having a great resemblance to granulitised pegmatites, are found in varying abundance within a gneissose or schistose matrix which might by itself be regarded as an altered shale or felspathic grit. In those places where the supposed pegmatitic material is in excess of the matrix, the rock assumes the aspect of a gneiss of igneous origin, and it seems possible that a considerable part of the whole series is composed of compound rocks of this character—of rocks, that is, of sedimentary origin which have been thoroughly permeated by pegmatitic material and thus converted into injection-gneiss or vein-gneiss ("adergneiss" of Sederholm).§ The proportion of pegmatitic material near Eilean a' Chlamhuinn, on the north side of the mouth of Loch Hourn, and at Rudh' Ard Slisneach, on the south side, is less than usual, and in this district a great part of the series has the aspect of altered somewhat felspathic sandy sediments, though it contains a great number of thin sill-like bands of hornblende-schist, which are not found in the adjacent Moine schists.

The limestones of Glenelg at once recall those of Letterewe and

* Mentioned by Macculloch, "Western Isles of Scotland," 1819, vol. i. pp. 53–55, and Sir R. I. Murchison, "Succession of the Older Rocks in the Northernmost Counties of Scotland," *Quart. Journ. Geol. Soc.*, 1859, vol. xv. p. 353, and subsequently by other authors.

† "Elemente der Gesteinslehre," 1901, p. 484.

‡ Since the above was written Dr. Flett has described the occurrence of andalusite in a graphite schist in the Lewisian Gneiss series at An Cruachan, Monar, Ross-shire ("On the Petrographical Characters of the Inliers of Lewisian rocks among the Moine gneisses of the North of Scotland," *Summary of Progress* for 1905, p. 155).

§ "Ueber eine Archäische Sedimentformation im Südwestlichen Finland," 1897 (*Bulletin de la Commission Geologique de la Finlande*), p. 133.

Gairloch, one-inch maps 91 and 92, and no doubt belong to the same Archæan series. The occurrence of graphite in certain of the schists in the above Ross-shire localities and in many of the Glenelg rocks * is also a notable coincidence, but it must be stated that in the latter area graphite has been found in rocks of very different types, including limestone and hornblende-schist, and it does not necessarily indicate the sedimentary origin of the rock in which it is found. In Glenelg it is perhaps a secondary constituent introduced at some period of metamorphism, as appears to be the case also in Ceylon and at Passau.†

It is perhaps possible, however, to suppose that the Glenelg graphite is all derived from certain beds, of sedimentary origin, which originally contained a good deal of carbonaceous or organic matter. Some of this matter may subsequently have been distilled into other rocks, including some of igneous origin, in the same way as ozokerite has been introduced into certain basaltic dykes and sheets which traverse the Carboniferous oil-shales of Midlothian. A. Osann considers ‡ that the graphite in the Archæan rocks of Canada has been derived partly from carbon, of organic origin, originally present in the limestone, but that the chief occurrences, in the form of veins etc., were probably introduced by fumarole action from sources deep down in the earth.

One important fact about the supposed pegmatitic material in the Lewisian Gneiss series of Glenelg, is that the greater part of it is in a granulitic condition and that it is frequently crossed by foliation planes, parallel to the axial plane of the folds which affect the country rock; while in the pegmatitic material in the adjacent Moine rocks the felspar is not often granulitic and foliation planes are but rarely present.§ It is also observed that the granulitic pegmatitic material is very abundant in certain parts of the Lewisian Gneiss close to the Moine rocks even in places where pegmatites of any kind are rare in these latter rocks, and, taking these two facts into consideration, it seems probable that most of the pegmatitic material at present existing in the Lewisian Gneiss in a granulitic condition has been introduced therein during some period of metamorphism which passed away before the beds which are now represented by the Moine rocks were deposited. The pegmatites which were subsequently introduced, both into the Moine rocks and the Lewisian Gneiss series, apparently in connection with a later period of folding and metamorphism, have not been so often or so completely granulitised, and perhaps they came in at the close of this period when the movements had almost ceased.

In isolated sections showing junctions of the Lewisian Gneiss with the Moine rocks there is not, as a rule, much difficulty in determining the line of contact, the rocks on either side having tolerably distinct

* The occurrence of black lead in Glenelg was noticed in 1764 by Prof. John Walker, "Notice of Mineralogical Journeys and of a Mineralogical System," *Edin. Philosophical Journal*, 1821–22, p. 88.

† Prof. E. Weinschenk, "Memoire sur l'Histoire Geologique du Graphite," Compte Rendu vii., *Congres Geol. Internat. Paris*, 1901. Reviewed by A. K. C. in *Geol. Mag.*, 1902, vol. ix. p. 180.

‡ "Notes on certain Archæan Rocks of the Ottawa Valley," *Report of the Geol. Survey of Canada*, 1902, p. 79.

§ Exceptions are mentioned subsequently in Chapter VII.

mineral characters. In some sections, for instance, on the south side of Glas Bheinn (north-east of Glenelg Bay), the two sets of rocks alternate in subparallel bands and lenticles, presumably in consequence of isoclinal folding, and there is very rarely any evidence of unconformity between the two. Where there is a distinct broad banding in the two, this appears as a rule to be parallel in each, and so also does the foliation and the direction of stretching. The more felspathic or more hornblendic character of most of the Lewisian Gneiss bands in these sections usually attracts attention, and in explanation of this and the other phenomena some observers have suggested that these bands may represent altered lavas or ash beds which are associated conformably with other rocks of sedimentary origin, belonging chiefly to the Moine series, as parts of one great geological formation.

When different sections exposing junctions at some distance from one another are compared, it is soon noticed that the rock of the Lewisian Gneiss series which comes next to the Moine schists and in some cases forms wide areas next it, is not always the same. In the scars on the north-east side of Glenelg Bay it is, for instance, a pink felspathic gneiss ; on the south-west side of Beinn a' Chuirn, it is a biotite-actinolite schist ; on the west side of the same hill (and about 550 yds. W.S.W. of Loch Coir' an Damh), it is a band of diopside ; three-quarters of a mile north of Beinn a' Chapuill, it is serpentine ; and so on. A somewhat similar state of matters exists, however, between the limestone and the various schists and gneisses of the Lewisian Gneiss series, and might be explained in some cases on the supposition that the original bands, and also the intrusions in them, were of an inconstant lenticular character.

In one locality, about a third of a mile E.S.E. of Rudha na h' Airde Beithe, nearly three miles south-west of the Kirkton of Glenelg, the examination of a small bare area, a few hundred yards long, shows a slight but distinct difference, amounting perhaps to 10° or 12°, between the strikes of the two sets of rocks ; * at the south-west end of the area a band of hornblende-schist lies next the Moine rock ; as we proceed north-east a pink felspathic gneiss comes in between the Moine rock and the hornblende-schist, and gradually increases in thickness to 30 or 40 ft., and still further on in the same direction another band of hornblende-schist intervenes between this pink gneiss and the Moine schist. And although indications of considerable stretching have been observed in all the rocks in this locality, and the line of junction of the two series has probably formed a line of special weakness, it does not seem probable that it represents a thrust-plane with visible displacement. In another adjoining locality, rather more than a third of a mile W.S.W. of Mam an Fhuarain, a clean rock face shows that there are some structures in the Lewisian Gneiss series which do not pass into the adjacent Moine rocks, and the margin of the latter † cuts some bands in the former at a slight angle.

The apparent conformity of the two series in most sections does

* In this locality also a bed which is supposed to represent an altered conglomerate occurs at the margin of the Moine series (see Chapter III.).

† Represented by a conglomerate-schist, the same bed as that referred to in the preceding footnote.

not exclude the possibility of their earlier representatives having once been markedly unconformable; for, during the isoclinal folding which affects both, there must have been great deformation of the original surfaces of contact, and a strong tendency to drag the earlier structures into parallelism, as well as to obscure them by a later foliation.

Various thin bands, including several of hornblende-schist and one of serpentine, transgress distinctly the adjacent bands of the series, and must represent intrusive dykes. A good many other bands of hornblende-schist also appear to cross the adjacent gneiss at a small angle, though they have been isoclinally folded with it. That the evidence of intrusion in these cases is not more marked may, again, be due to the drag and deformation experienced during folding. These sharply folded basic bands must certainly have been in existence before the period of metamorphism which affected the Moine rocks and the Lewisian gneiss alike, and, as similar bands are hardly known in the adjacent Moine rocks, it seems probable that the original representatives of most of them were formed before the representatives of the Moine rocks.

We shall now proceed to describe some of the more important types of rock which compose the series.

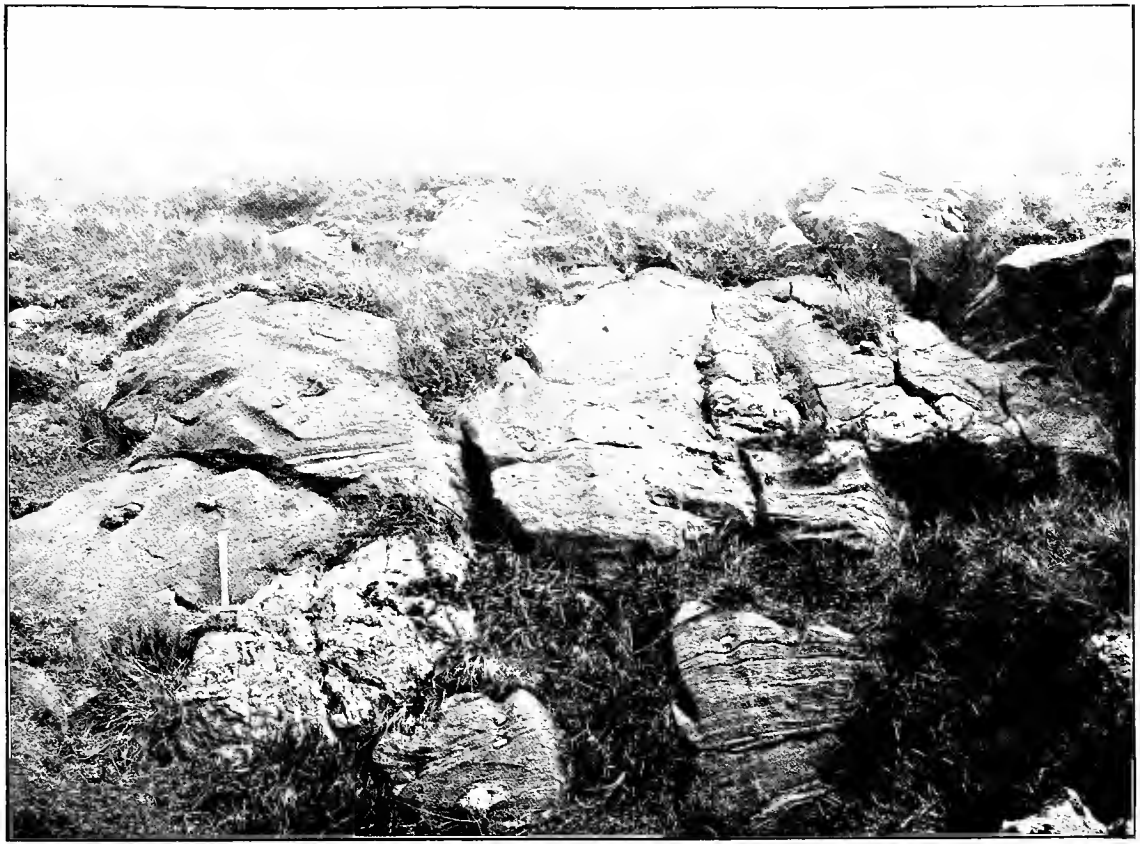
LIMESTONES, CALC-SILICATE-BANDS AND CALCAREOUS GNEISSES.

Limestone of a tolerably uniform character is seen at frequent intervals most of the way between Totaig, on Loch Alsh, and Loch Hourn. Fresh fractures are of a white colour, and the carbonate grains are often larger than a mustard seed and consist chiefly of calcite, but dolomite also frequently occurs. Forsterite is an abundant constituent, and Dr. Teall states that the marbles which contain it are similar in structure and composition to those of Assynt and Skye * which are known to have been formed by the contact-metamorphism of dolomites. It is, therefore, highly probable that the original rocks were more or less siliceous dolomites, and that they have been wholly or partially de-dolomitised by the development of the magnesian silicates, forsterite and tremolite, which are common in the marbles.

As Dr. Teall explains in the works referred to, diopside (CaO, MgO, $2SiO_2$), may be formed from dolomite (CaO, MgO, $2CO_2$), by the simple substitution of silica for carbon dioxide. But neither forsterite ($2MgO$, SiO_2), nor tremolite, in which the ratio of CaO : MgO is 1 : 3, instead of 1 : 1, as in dolomite, can be so formed without a certain amount of de-dolomitisation.

In many places there is a good bedded or banded appearance, owing chiefly to the existence of subparallel layers, from half an inch to four inches broad, which contain less forsterite than the intervening layers. The limestone often forms two, three, or more subparallel bands, but these may possibly all be parts of one bed repeated by folding. The individual outcrops are, in places, as much as 150 yds. broad, but the original thickness perhaps need not have exceeded

* *Summary of Progress* for 1900, p. 151. See also Chapter XXXI. of the "Geological Structure of the North-west Highlands of Scotland," *Mem. Geol. Survey*, 1907.



Outcrop of Limestone on hillside a mile and a half east of the Kirkton of Glenelg. The large projecting white lumps are chiefly composed of diopside.

20 or 30 ft. Among many good exposures we may specially call attention to those along the broad repeatedly folded band which stretches from Totaig in a south-west direction, for about two miles and a half, and to the higher band which crosses Allt Easan Mhic Gorraidh, nearly a mile W.N.W. of Beinn a' Chuirn, and passes into the Glenmore of Glenelg.

The included pieces of different silicates, among which are diopside, forsterite, phlogobite, tremolite, serpentine, spinel and black hornblende, are so numerous that in many places they form perhaps nearly half the rock, and give a rough face to weathered exposures, as is well seen in Plates II. and III. The diopside generally forms masses from a few inches to several yards in breadth which are edged by a rim, often about half an inch thick, of some dark green serpentinous substance. None of the smaller serpentine pieces, less than a hazel nut, show, however, any kernel of diopside, In one locality, rather more than a mile east of Ardintoul (south side of Loch Alsh), the needles of tremolite have been folded into shapes resembling the letter " V " (Plate VII. Fig. 1), and crossed by strain-slips : in others, thin strings of pale green fibrous hornblende are found along lines of movement, which, on the hillside 1000 yds. north-west of Bailamhuilinn, are seen to traverse and fault the diopside-serpentine lumps. The phlogopite varies considerably in abundance and size, and is occasionally found in large poikilitic plates (enclosing grains of calcite) as much as three or four inches long. The forsterite, though nearly always abundantly represented, is generally in small rather round pieces, often from two to three millimetres in length, and has often been wholly or partially converted into serpentine. It has been isolated and analysed by Dr. Pollard with the following results :—*

SiO_2, Silica	41·16	(trace of TiO_2)
Al_2O_3, Alumina	1·02	
FeO, Ferrous Oxide	2·00	
CaO, Lime	·26	
MnO, Manganous oxide	·26	
MgO, Magnesia	54·86	
Loss on ignition	·70	(trace of F)
	100·26	

Or, SiO_2 : (Mg, Fe, Ca, Mn) O : Al_2O_3
·687 : 1·411 : ·01

Specific gravity 3·24. The small amount of alumina is probably due to a trace of spinel.

Garnet appears to be very rare, but occurs in some thin impure bands at the top of an exposure about 1000 yds. W.N.W. of Lochan an Beinn Faide, in association with black mica, hornblende and siliceous lumps.

The spinel is not abundant, but has been found 1200 yds. east of Sgiath Bheinn, 1600 yds. north-west of Beinn a' Chapuill, 370 yds. N.N.E. of Balvraid (Gleann Beag of Glenelg) and other places. It generally occurs embedded in lumps, often two or three inches long,

* " On Spinel and Forsterite from the Glenelg Limestone (Inverness-shire)," Mr. C. T. Clough and Dr. W. Pollard, *Quart. Journ. Geol. Soc.*, 1899, vol. lv. p. 379.

which project slightly from the rest of the rock, and weather with a brown crust. These lumps contain also serpentine, calcite and scales of phlogopite, but the spinel forms as much as a sixth part of some of them, and occurs in small octohedral forms, often rather less than a pea, which vary in colour from dark green (almost black) to pale blue and purplish red. Dr. Pollard has found the specific gravity to be 3·57, and the chemical composition as follows :—*

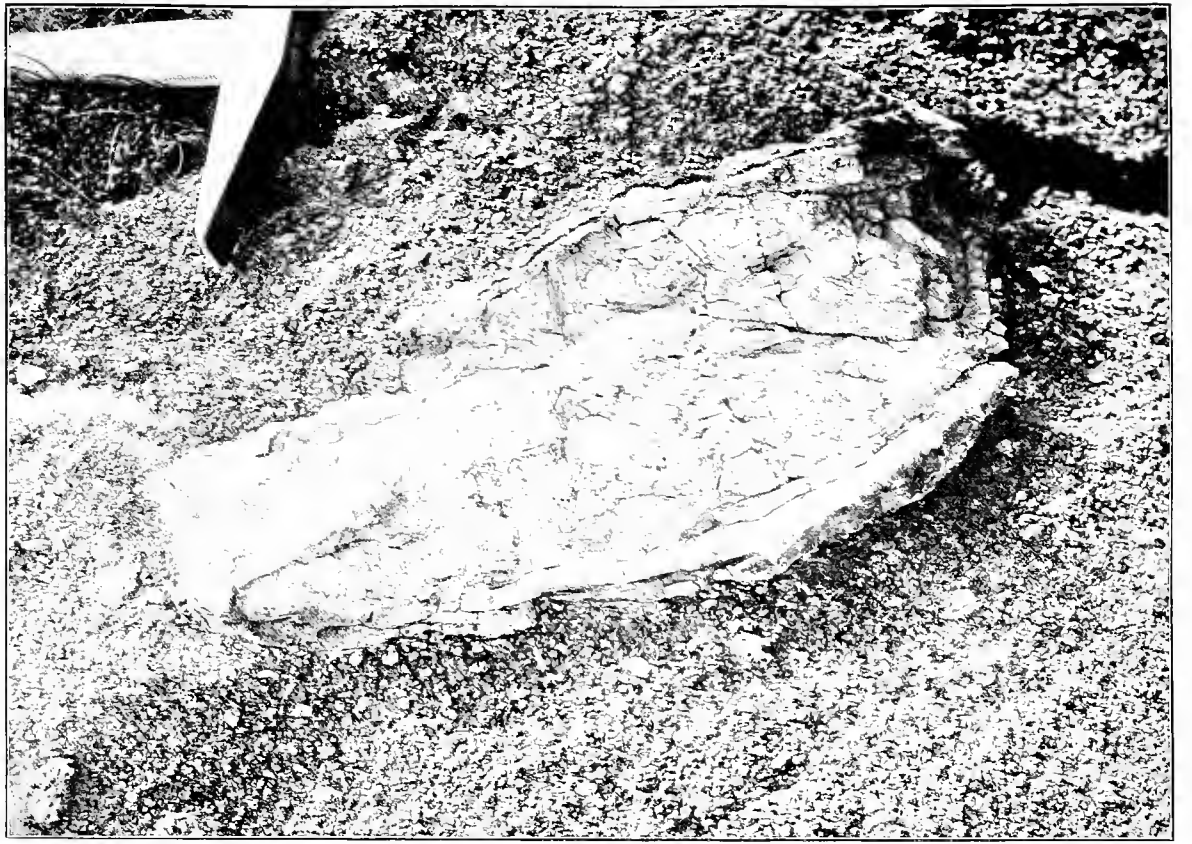
SiO_2, Silica	1·20
Al_2O_3, Alumina	69·80
FeO, Ferrous Oxide	2·03
MgO, Magnesia	27·30
	100·33

Or, SiO_2	:	Al_2O_3	:	(Fe,Mg)O
·03	:	1	:	1·04

In a few places, scales of graphite have been found within the limestone, for instance in quartzose lumps within the limestone 170 yds. north-west of Iomairaghradan, and in lumps of diopside 500 yds. slightly east of south of Corrary.†

Near junctions with other rocks of the Lewisian Gneiss series, the limestone often contains crystals of dark hornblende and thin bark bands which appear to be chiefly composed of this mineral. The actual margin is not as a rule sharply defined, but is represented by an edge-rock, sometimes more than a foot wide, which is to a large extent composed of black hornblende and epidote. In other places an edge rock is composed of diopside and pink felspar (oligoclase-andesine in 8649). The rocks outside these edge rocks vary a good deal from place to place, a fact which may be partially explained on the supposition that rocks of igneous origin come up to the limestone in certain places, while in others they do not. Immediately under one of the exposures on the north side of the Gleann Beag of Glenelg ‡ there is a schistose rock, containing many small flakes of brown mica and specks of pyrites, which has a close resemblance § to certain metamorphosed sediments in the Braemar Highlands. In other places, but particularly often on one side of the numerous exposures near Creag Reidh Raineach (a mile within the adjoining one-inch sheet 72), the rock adjacent to the limestone is a garnetiferous brown biotite-schist, containing kyanite in such abundance that it must be considered to represent an old aluminous sediment. Again, on the hill nearly two-thirds of a mile slightly south of east of Lochan Cul a' Mhoirt (south side of Loch Alsh), a little distance away from the limestone a pinkish gneissose rock (7908) is found, which is essentially composed of layers of zoisite and microcline, mixed with other dark layers of pyroxene, calcite and sphene, and this rock is stated by Dr. Teall to be allied to rocks found in close association with limestones in Donegal and in the South-Eastern Highlands.

* *Op. cit.*
† These last were found by Mr. A. K. Coomáraswámy.
‡ About 1060 yds. north-west of Corrary.
§ To which attention was called by our colleague Mr. G. Barrow.



NEAR VIEW OF LIMESTONE. Allt Easan Mhic Gorraidh, a mile and a half north of Bealary, Glenelg.
A large projecting piece of diopside is sheathed with serpentine.

In various places the rocks on the two sides of one narrow outcrop of limestone are so different in character from one another that the outcrop cannot be regarded as part of a folded band with the same rock on either side. This is a consideration of some importance, for it shows that the limestone cannot easily be regarded as an independent formation of different age from all the other rocks of the Lewisian Gneiss series. An instance of the kind referred to is seen on the coast 60 yds. east of Totaig pier, where, on the north-west side of an outcrop of limestone about ten yards wide, there comes a massive garnet amphibolite, while on the other side there are thin alternating bands of gneiss of various characters, but generally hornblendic. Still more striking instances occur near Creag Reidh Raineach, where, on one side of the limestone, we usually find the garnetiferous biotite-kyanite-gneissa lready alluded to, and, on the other, thin flaggy alternations of hornblendic gneiss.*

Near the bands of limestone of the type described, we often find other bands of different character, which may represent impure calcareous rocks. These bands are always thin and generally contain a considerable proportion of quartz and felspar, in addition to tremolite, sphene, pyrite, pyrrhotite and graphite (7685–7688 inclusive). The pyrite and pyrrhotite are often associated with a small proportion of gold (see Chap. XIV.), and give a rusty and carious appearance to the weathered rock. Good examples, which are shown by dark streaks in the published map in consequence of their richness in graphite, are seen in the following places: at the roadside 340 yds. slightly west of north of Bailamhuilinn, rather more than a quarter of a mile S.S.E. of Beinn Fhada (south-west of Totaig), and 730 yds. W.N.W. of the south-west end of Lochan na Beinne Faide (a mile and a half S.S.W. of Totaig). In the last mentioned locality the graphite occurs in crumpled scales, sometimes more than an inch in length, and is also packed into irregular lumps and veins, occasionally as much as an inch or two in breadth: some of the veins may be traced across several felspar individuals, and it appears as if the graphite, being of a soft yielding nature, has been squeezed into later cracks. The felspar in this rock (9336) belongs to the oligoclase-andesine series.

A few other calcareous bands of a third type are also found, in which we find subordinate grains of calcite lying between scales of biotite and chlorite. These bands are not unlike certain others which elsewhere in the North of Scotland can be shown to have been produced by the shearing down of basic hornblendic bands of igneous origin, and they may perhaps have been formed in a similar manner. The best examples of this type are seen about 300 yds. above the foot of Allt Easan Mhic Garraidh (rather more than two miles north-east of the Kirkton of Glenelg).

* In various places in this locality, the limestone does not occur where we should expect to find it, along the junction of these two rocks. This may be due to squeezing out during folding, but on the other hand it seems not impossible that it may indicate an intrusion of some igneous rock (now represented by the flaggy gneiss) across the limestone. We could not expect any igneous rock which had been sharply folded with the limestone, to show such clear evidence of transgression across it as some of the later intrusions do. A third possible explanation is, that the limestone has in places been dissolved away, as certain carboniferous limestones have occasionally been ("The Disappearance of Limestones in High Teesdale," *Geol. Mag.*, 1903, vol. x. p. 259).

BIOTITE-SCHIST, GARNETIFEROUS BIOTITE-KYANITE-GNEISS, GARNETIFEROUS GRANULITIC-BIOTITE-GNEISS AND SOME ALLIED ROCKS.

The rocks now to be described have not been mapped in detail, but they are known often to occur either at or near the sides of the limestones, and it seems probable that many of them represent clayey or shaly members of the same old greatly altered sedimentary formation as that to which the limestones belong.

The brown biotite-schist with pyrites, which underlies the limestone 1060 yds. north-west of Corrary, in the Gleann Beag of Glenelg, is a somewhat exceptional type, and shows no distinct garnet or kyanite. A good exposure of biotite-schist of more common character is seen a little further up the Gleann Beag, among the crags rather more than a quarter of a mile north-west of Corrary, where there is a band, about 15 yds. wide, which contains abundant garnets about the size of peas, as well as prisms of kyanite (7939), some of which are of a blue colour and more than half an inch long. The biotite is of a brownish colour and is associated with white mica, which is in greater abundance than is usual in the other biotite-schists of the Lewisian Gneiss series. This band is rather more than 100 yds. off the nearest exposure of limestone; it is bordered on the west by a broad belt which consists chiefly of sheared pegmatite and on the east by a band, eight feet thick, of brown-weathering pyritous garnetiferous schist of a more siliceous character.

Biotite-schists, somewhat similar to that just described, are well seen at the sides of or near the limestone outcrops east and south-east of Meall Buidhe (three miles slightly west of south of the Kirkton of Glenelg) at frequent intervals for a length of more than a mile. The kyanite is unusually distinct in an exposure about 150 yds. W.S.W. of the outlet of the loch, but kyanite is by no means always visible, and in many places it has been replaced by some greenish micaceous substance, apparently the "shimmer aggregate" of Mr. Barrow.* In some places, for instance at the side of the alluvium a mile S.S.E. of the Ordnance Station on Meall Buidhe, the rock is graphitic, and in various localities it is associated with, or passes into, a more siliceous schist, which is also highly garnetiferous.

In the crags on the north side of the Glenmore of Glenelg about 100 yds. north of the road north of Bailambuilinn, a garnetiferous biotite-schist or gneiss is well exposed, and shows in some parts distinct scales of graphite, and in others crystals of a pale bluish mineral which is probably kyanite (7914). The exposure, which is about 60 yds. broad, lies a few yards south-east of a limestone outcrop, and is only separated from another limestone outcrop by some thinly banded gneisses of no great breadth. This kyanite-bearing rock is in most parts paler and more siliceous than the rocks just referred to near Meall Buidhe, and it is difficult to see much difference between it and the garnetiferous biotite-granulite or granulitic gneiss which forms one of the commonest rock types in the Glenelg district. A rock of the common type just referred to occupies most of the area which extends south-westward from the wood near Totaig for more than

* "On an Intrusion of Muscovite-Biotite Gneiss in the South-Eastern Highlands of Scotland, and its accompanying Metamorphism," *Quart. Journ. Geol. Soc.*, 1893, vol. xlix. p. 340, plate xvi. fig. 5.

two miles along the strike, and across the strike for an average breadth of about half a mile, between the two sets of limestone outcrops shown on the map. The biotite is often brown but not universally so. The garnets are often the size of small peas and are extremely abundant, but they have not as a rule good idiomorphic outlines, and are often margined or crossed by thin films of chlorite or biotite, which appear to be replacing part of their substance. Specimen 7912 was collected as a representative of this type. It is mainly composed of quartz and felspar (oligoclase and orthoclase) and is granulitic in structure. Garnetiferous granulitic gneisses on the same strike and with a good deal of biotite, generally of a brown colour, are well exposed also on the coast between Totaig and Letterfearn and in the little burn at the south margin of the Totaig wood, in which localities it repeatedly alternates with hornblende-schist and thin seams (represented by specimen 9184, obtained from one of a series of parallel seams averaging perhaps no more than an inch in thickness) which probably represent eclogite. In one locality, about 1200 yds. S.S.W. of Totaig pier, a considerable area, perhaps 3000 sq. yds. in extent, is composed of a rock which consists chiefly of garnets and quartz, but contains also crystals of kyanite and lumps of shimmer aggregate. On the same strike, in a flattish exposure in the hillside, 220 yds. south-west of Tigh Druideig, is found a still more remarkable rock, about half of the substance of which, for an area of several square yards, is composed of kyanite or of its representative shimmer aggregate: the kyanite sometimes occurs in poikilitic individuals, at least four inches long, which enclose garnet. In slide 9339, representing a portion of this peculiar rock, staurolite may be present in addition to garnet, biotite, white mica, kyanite and chlorite.

One of the best graphitic seams in the district occurs in a variety of this garnetiferous biotite-gneiss, about 120 yds. S.S.E. of the south-west end of Lochan Beinne Faide (a mile and a half S.S.W. of Totaig), which itself contains scattered scales of graphite, but this seam is never more than eight or nine inches broad and has not been traced more than 20 or 30 yds. It is mainly composed of graphite and quartz (9333), while a specimen of the adjoining rock (9334) contains also garnet and brown mica.

The largest area formed almost entirely by the more micaceous biotite-schist or gneiss is that on the north side of the Gleann Beag between the old Dun above Balvraid and the east side of Ruighe na Corpaich. Almost the whole of the Druim Iosal is composed of this rock, and crags several hundred feet high afford excellent sections. In the common type the biotite is in large brown scales, and there is no distinct white mica; the garnets are often closely packed and without good idiomorphic form; the kyanite is often very conspicuous and sometimes intergrown with garnet to form lumps almost as large as a hen's egg (about a mile west of the north end of Loch Iain Mhic Aonghais); dark hornblendic lumps and lenticular layers are tolerably common but rarely exceed five or six inches in thickness; pale grey seams, often a few inches thick and composed of thin subparallel laminæ of quartz and felspar, both in a finely granulitic condition, are tolerably common, and may locally be so numerous that they form nearly half the rock mass. They sometimes contain garnets, but are

very irregular in distribution and probably represent old pegmatitic veins which have been sheared and granulitised since their introduction. Other veins of pegmatitic material are also found in a much less sheared condition, and must have been introduced at a later period.

On a first traverse the impression might be, that the biotite-garnet kyanite-gneiss just described belonged to the pelitic gneiss of the Moine series—so strong would be the suggestion that the rock here before us was of sedimentary origin. But the scarcity or absence of white mica, the brown colour of the biotite, the abundance of kyanite, the character of the hornblendic laminæ, and the presence of the thoroughly streaked out and granulitised pegmatitic veins, all tend to show that such an impression would be incorrect. The hornblendic layers are sometimes mainly composed of black hornblende, or of black hornblende and biotite, and are readily distinguished from the hornblendic seams which are sometimes found in the pelitic bands of the Moine series, by the comparative absence of quartz, zoisite and garnet. Moreover, thoroughly streaked out and finely granulitic pegmatites have hardly ever been observed in the Moine rocks of this district.

The following analysis of a specimen (13250) of this biotite-kyanite-gneiss, taken from a locality 1050 yds. E.S.E. of Balvraid, has been executed by Mr. Radley:—

SiO_2	55·82
TiO_2	1·10
Al_2O_3	18·91
Fe_2O_3	1·80
FeO	8·43
MnO	·21
(CoNi) O	·04
BaO	nt. fd.
CaO	2·23
MgO	5·38
K_2O	2·48
Na_2O	1·22
Li_2O	trace
H_2O at 105° C.	·19
H_2O above 105° C	1·66
P_2O_5	·09
	99·56

Traces of pyrites and chlorine.

It will be noticed that (1) the percentage of alumina is high, (2) the potash is in considerable excess over the soda, and (3) the magnesia over the lime, so that the chemical similarity between this rock and the common phyllites and clay slates is great.*

The margins of the Druim Iosal gneiss are considerably obscured by drift, and the immediately adjoining rocks are not well seen. In one place, near the northern end of the area, a band of diopside, no doubt representing limestone, is exposed a little below the gneiss, while in another locality, 150 yds. E.N.E. of the Dun, a hornblende-

* See for instance, Rosenbusch, " Elemente der Gesteinslehre " (1901), p. 450.

schist lies immediately under it. The area chiefly occupied by the biotite-gneiss is less diversified by outcrops of hornblende-schist and hornblendic-gneiss than the adjoining areas occupied by other types of rocks belonging to the Lewisian Gneiss series usually are, but it is not wholly free from such outcrops, as may be seen on the hillside about a quarter of a mile west of Ruighe nan Corpaich, and again on the north side of the old river terraces half a mile east of the Dun.

A rock like that of Druim Iosal forms large areas about a mile within the adjoining one-inch map 72, near Creag Reidhe Raineach, and stretches thence southward at least as far as the foot of An Leth Allt, a distance of two miles. As already stated, this is often seen in contact with limestone and clings to it through a series of very complicated folds. It sometimes occurs on both sides of a limestone outcrop, which presumably occupies the central portion of an anticline or syncline, but in other places we find it forming one of a succession of three rocks, in which the limestone is the middle member, being bounded on the one side by thin banded hornblendic gneisses, and on the other by the garnetiferous biotite-kyanite-gneiss. The area occupied by the biotite-gneiss is again comparatively free from hornblende-schist and hornblendic gneiss, but in one place, about 200 yds. south-west of the Creag, a biotite-hornblende-schist of considerable thickness comes in between the biotite-gneiss and the limestone.

GRANULITIC BIOTITE-GNEISS, GENERALLY WITHOUT GARNETS.

Certain granulitic biotite-gneisses which are rich in garnet and often occur in close association with the biotite-kyanite-gneiss have been already spoken of, but other tpyes which are generally devoid of garnets and seem best developed at considerable distances from the kyanite-gneiss and limestone still remain to be described. Gneisses of these last types form perhaps the commonest rock in the Lewisian Gneiss series all the way from the north side of Glenelg Bay to the mouth of Loch Hourn, though they are in many places closely mixed with bands of hornblende-schist and other rock, as is shown in Plate IV. Near Angalltair and at the back of the raised beach south-west of the Kirkton of Glenelg, they form high cliffs, which have a pinkish colour in the landscape, a colour which, on close examination, is found to be chiefly due to the great number of pinkish felspathic spots and streaks—the latter often in the form of parallel rods rather than continuous laminæ—which traverse the somewhat greyer body of the rock. These spots and streaks, though generally only an inch or less in breadth, are so abundant that over considerable areas they form nearly half the rock. A good number of the laminæ attain the thickness of a foot; one well defined band, half a mile S.S.W. of Glenelg pier, is five or six feet thick, and another as much as ten or twelve feet. They have a habit of coalescing and branching, and of rapidly bulging or dying out, behaving as if they were independent of the rock in which they occur. They consist mainly of reddish felspar with streaks and spots of translucent quartz, and contain little or no mica, while in the greyer rock, which behaves as their host, small flakes of biotite are abundant, and the grains of quartz and

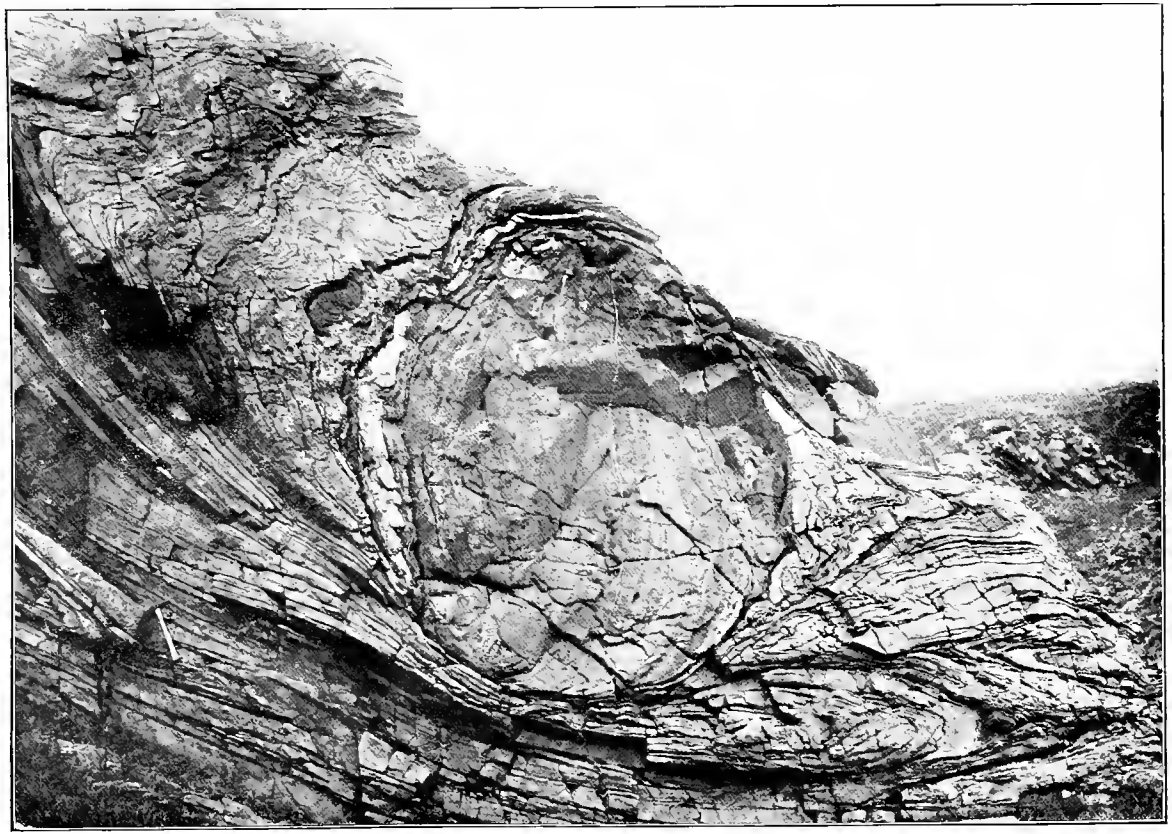
felspar are distributed more evenly and are often mixed with a considerable proportion of epidote. The red spots and streaks remind one very much of the little pegmatites which occur in such abundance in certain rocks of the Moine series, but they differ from them in two respects, first in the felspathic constituents being almost universally in a granulitic condition, and secondly in being often crossed by a foliation—nearly horizontal in many places—parallel to the axial planes of the folds which affect the country rock.

Taking these facts into consideration, together with the further fact that felspathic pegmatites of any kind are rare in the Moine rocks so far east as this, as is seen on examining the Moine crags at Bernera and between Rudha a' Chamas Bhàin and An Gurraban, it seems probable that the pink felspathic streaks just described were in existence before the rocks which now represent the Moine series were deposited. These streaks have been so folded and altered together with the rock in which they occur, that they are now sometimes difficult to distinguish and they form with the other ingredients of the rock a veined gneiss ("adergneiss" of Sederholm), of which the composite character is not evident on first examination. Most of the veined rock in which these pegmatitic streaks occur may be called a granulitic biotite-gneiss. It could probably be matched with various gneisses which elsewhere, further north, are known to have been formed during shearing from gneisses which are probably of igneous origin, but it seems also possible that it may represent an altered form of the more sandy members of the same formation as that to which the limestone belongs. It is more felspathic than the usual type of the psammitic rocks of the Moine series, but if we could by any means thoroughly shear out and granulitise some of these psammitic rocks in areas where they have previously been highly pegmatised, as for instance on the hillside a little east of Strath a' Chomair (head of the Gleann Beag), it is doubtful whether we could discern much difference between the two.

Rocks with a considerable resemblance to these veined biotite-gneisses of the Kirkton of Glenelg extend along the strike for a considerable distance in a south-west direction, and are well exposed on the north side of the mouth of Loch Hourn, especially between the Rudha Caol and the first band of Moine rocks east of Rudha a' Chasteil. In some localities these granulitic gneisses are very closely intermixed with thin sill-like bands of dark hornblende-schist with which they are repeatedly folded into sharp isoclines with the axial planes inclining E.S.E., and they are themselves found on close examination to contain a considerable admixture of needles of hornblende. In other places, however, as for instance between 100 and 170 yds. E.S.E. of Eilean a' Chlamhuinn, there is not much mixture of hornblende-schist, and the pegmatitic eyes and streaks are also rarer than usual, so that the rock does not appear to differ much from certain varieties of the Moine rocks. We can occasionally see a distinct and rather close alteration of parallel bands, some more and others less micaceous, which closely simulate bedding, and which, being crossed by the foliation which is parallel to the axial planes of fold, must have been in existence before the folding of which this coast bears such eloquent testimony.

The following analysis of a specimen (13251) of the granulitic

BANDED LEWISIAN GNEISS. Coast near Rudha a' Chasteil, Loch Hourn. Most of the dark bands are composed of hornblende-schist.



LARGE KNOT OF FOLIATED BASIC ROCK IN LEWISIAN GNEISS. Coast near Rudha Caol, four and a half miles S.S.W. of the Kirkton of Glenelg.

biotite-gneiss taken from a locality 120 yds. E.S.E. of Eilean a' Chlamhuinn has been executed by Mr. Radley :—

SiO_2	70·45
TiO_2	·43
Al_2O_3	14·86
Fe_2O_3	1·34
FeO	1·46
MnO	·23
(CoNi)O	·04
BaO	nt. fd.
CaO	3·18
MgO	1·47
K_2O	1·10
Na_2O	4·92
Li_2O	trace
H_2O at 105° C.	·04
H_2O above 105° C.	·49
P_2O_5	·11
FeS_2	trace
	100·12

The analysis provides no further argument in favour of regarding the rock as a paragneiss. The considerable excess of soda over potash is an unusual feature in sediments and paragneisses but can be matched in some of these.* It might, perhaps, be due to the intimate impregnation with pegmatitic material.

In certain places, but particularly a little E.S.E. of Rudha Caol, a biotite-granulite, which seems of the common type, winds round many knots and lenticles of dark basic rock, varying in size from a fist to masses two or three yards broad and ten yards long, in the direction of the strike. These basic rocks vary in composition, some being chiefly composed of dark green hornblende, with scattered flakes of brown mica and specks of pyrites, while others are made up of subparallel bands of varying character, some of which contain a considerable proportion of quartz and felspar. The bands in the banded knots occasionally end abruptly at the margins of the knots, while the laminæ of the paler, enclosing gneiss sweep past their ends, as seen in Plate V., in much the same way as the somewhat acid gneisses of the west coast of Sutherland cut across the ends of included masses of earlier consolidated more basic gneisses. It is suggested from this that the enclosing rock near Rudha Caol is also of igneous origin.† Some of the laminæ of the granulite are also enormously thinned or squeezed away near the sides of the knots.

Many of the pegmatitic streaks and spots which occur near the mouth of Loch Hourn have not been so thoroughly granulitised as those already described near the Kirkton of Glenelg, and we often find in them, but perhaps particularly on the coast between 200 and 270 yds. E.S.E. of Rudha Mor (l.w.m.), broad cleavage faces of felspar,

* See for instance, Rosenbusch, " Elemente der Gesteinslehre " (1901), p. 442, analysis 17.

† It must be remembered, however, that somewhat similar basic knots, with their component bands ending sharply at the sides of the knots, are also found within the quartz-granulites of the Gairloch and Loch Maree district. These granulites are supposed to be of sedimentary origin, but they must at one period have been in a soft condition and in a state of flow like that of many igneous rocks.

an inch or more in breadth, which gradually tail out at each end into long granulitic streaks and are also crossed by similar streaks. It is noticed that the granulitic felspar is always of a reddish colour, though the ungranulitised eyes are usually almost white, and that, both in the granulitised pegmatites and the greyer gneiss in which they occur, small pieces, about the size of a pea, of black orthite with gummy lustre are not uncommon.

A black lenticle which is mainly composed of orthite has also been found in a fine-grained hornblende-biotite-gneiss on the north side of Eilean Rarsaidh (Loch Hourn). It lies parallel with the foliation, which is vertical in this locality, and has been followed downwards for five or six inches without reaching the bottom: the length along the strike is nine inches and the breadth three. No other similar lenticle was found, but on microscopic examination the adjacent rock (11631) is seen to include orthite zoned with epidote, as an accessory constituent. Dr. Teall gives the following description of this orthite lenticle (11692, 11630, 11645, 11646, 11658–11663): "The rock is black with a pitchy or resinous lustre, and closely resembles in general appearance the orthite from Arendal in Sweden. It is mainly composed of orthite, which occurs in large irregular individuals with low double refraction and no marked cleavages. The colour by transmitted light varies from brownish to greenish. In all sections examined the orthite is associated with quartz and a uniaxial, positive, tetragonal mineral, having a high refractive index and strong double refractive (zircon ?). In some specimens biotite, sphene, pyrite and a colourless mineral or minerals of varying double efraction belonging to the epidote-zoisite group are also present."

The small patch belonging to the Lewisian Gneiss series near Rudh' Ard Slisneach (south side of Loch Hourn) consists chiefly of granulitic biotite gneiss, with small knots and streaks of biotite and hornblende and some bands of hornblende-schist. This gneiss seems, in places, to be composed of an intimate mixture of two varieties of rock not very easy to separate, one of which is pinker and more felspathic than the other. The paler rock (9846) is in places decidedly calcareous, but seems to consist in the main of muscovite, biotite, quartz and various felspars.

ECLOGITE, GARNET-AMPHIBOLITE, CERTAIN HORNBLENDE-SCHISTS AND OTHER ALLIED ROCKS.

The rocks to be now described form one of the largest group in the Lewisian Gneiss series of the district. It is probable that a good many of the foliated basic rocks, if they were thoroughly examined, would be found to belong to the class which shows intrusive sections; but there can be little doubt that the eclogites, and also many of the hornblende-schists, correspond in their field relations to the "early basic" rocks of Sutherland, with which, also, they have close petrological affinities.

Eclogite proper, the rock which forms the most striking variety of the group, and which was first described by Dr. Teall * from a specimen (1805) collected by Sir A. Geikie, is usually a massive

* "On an Eclogite from Loch Duich," *Min. Mag.*, 1891, vol. ix. p. 389.

rock, so free from any regular foliation that it might at first be mistaken for some rock intruded into the series after the cessation of most of the folding, but on examination it is found to be intricately mixed with thin veins of more acid material, and to pass outwards into numerous thin seams more or less allied to eclogite, separated by thin parallel layers of paler acid gneiss. The thin banded series so formed is often folded into sharp isoclines. Many of the hornblende-schists, also, are traversed by numerous strings of some paler more acid rock, as may be seen between the mouth of the Glenelg river and Creag Mhor, and in part of the burn rather more than a third of a mile slightly east of north of Mam an Fhuarain.

The margins of these rocks are indeed often of an extremely complicated character, and in this district no general attempt to map them has been made, though a few bands of hornblende-schist have been traced in Skye and in the neighbourhood of the Kirkton of Glenelg.* Their main areas have, however, been noted, and it is clear that the eclogite and the closely allied garnet-amphibolite are very frequently found close in the immediate neighbourhood of limestone outcrops. The typical eclogites have not, indeed, been seen in actual contact with limestone, but they are very abundant only a few yards away, probably indeed more so than in any other position. These rocks form, for instance, an almost continuous margin on the south-east side of the limestone which extends in a south-west direction from the south-west corner of Totaig wood to the county boundary, and are also frequently seen close to the limestone rather more than half a mile east of Sgiath Bheinn (half a mile south-east of the Kirkton of Glenelg). We thus get as close companions the two rocks,—eclogite and limestone,—which would by many geologists be chosen as the best representatives of the two great classes of rocks, of igneous and sedimentary origin respectively, into which it seems probable that the Lewisian Gneiss series may be divided.†

For examples of exposures found considerable distances away from limestone, we may refer to those on the west side of the bridle-path between the Kirkton of Glenelg and Ardintoul for three-quarters of a mile south-west of the county boundary, and to others, which extend with occasional interruptions for nearly two miles along the strike, a little east of the broad band of Moine rocks which is mapped on the east side of Monadh nan Lochan.

The typical eclogite is, as said, a massive rock, and is distinguished by the intimate blending of rather pale green with deep red colours, the former due to omphacite and the latter to garnet, but it often appears to pass insensibly into equally massive garnet-amphibolite, in which the pale green omphacite is replaced by a darker hornblende. Occasionally these rocks show a banding, but of such irregular dis-

* Those which show no indication of intrusive character are not coloured in the published map, but their margins have been engraved.

† F. Becke ("Über Mineralbestand und Stuktur der krist. Schiefer," *Sitzungber. Wiener Akad.*, 1903, and Dr. Grubenmann ("Die Kristallinen Schiefer," Berlin, 1904, quoting F. Becke), regard eclogite as an altered form of gabbro, produced at a great depth and pressure in conformity with the Law of Volume, according to which the constituents of rocks formed near the surface rearrange themselves at greater depths and pressures, so that new minerals, which are of greater specific gravity and take up less space, are formed in lieu of the original ones. The garnet in eclogite may have been derived from a mixture of olivine and anorthite, or from augite and anorthite, the latter change being accompanied with the liberation of some quartz.

position, often winding round large, massive *augen*, that it is impossible to discern any general strike or dip.

The garnet and the omphacite, which has no definite crystalline form, and is sometimes seen to include garnet, vary considerably in relative abundance. The garnets are often idiomorphic and about the size of peas, but in other parts, even in the same hand specimen, they may occur in round grains. In certain localities near Monadh nan Lochan, they are edged by thin rims composed of granules of white felspar or of epidote, and seem occasionally to be entirely replaced by small spots composed of felspar or epidote. In other localities magnetite sometimes occurs in tolerable abundance in close association with the garnet. The garnet in a specimen of typical eclogite, collected from a locality rather more than half a mile slightly east of north of Beinn a' Chapuill, has been isolated and analysed by Dr. Pollard,* who found the specific gravity to be 3·74, and the chemical composition as follows :—

SiO_2	40·3
TiO_2	Trace
Al_2O_3	21·6
FeO	18·0
Fe_2O_3	1·3
MnO	·7
CaO	7·2
MgO	11·2
	100·3

The exposures on the shore near Totaig Ferry, the locality from which the specimens first described by Dr. Teall were collected, are not extensive though somewhat numerous. A small one, just east of the Ferry-house, lies between two bands of limestone about 40 yds. apart, and, 70 yds. south-east of the eastern band, thin parallel layers, about an inch thick, which seem also composed of eclogite or of garnet-amphibolite, are interbanded with the garnetiferous biotite-gneiss. About 550 yds. south-east of the pier, a band about 12 yds. wide, composed of eclogite and garnetiferous hornblende-schist, strikes E.N.E., and a little further south-east there is a big, nearly round mass of eclogite, which is wrapped over by a banded gneiss, itself partly composed of thin seams of eclogite or of some allied rock. Similar banded gneisses are also well exposed in the stream on the south side of the Totaig wood, and a little south of this stream (about a quarter of a mile slightly south of west of Tigh Dhruideig) there are large exposures of banded eclogite with bands and lenticles, about an inch thick, which differ considerably in their relative proportions of garnet and omphacite, some being almost entirely composed of the one mineral and others of the other: quartz is also occasionally developed in stripes or rods, about an eighth of an inch thick, parallel to these bands.

From the frequent association and gradual passage of eclogite and garnet-amphibolite into hornblende-schist — an association which is well seen in the exposures already referred to near Monadh nan Lochan and in a scar 1000 yds. W.S.W. of Tigh Dhruideig—it might be thought that the latter rock has often been formed from

* *Summary of Progress* for 1899, p. 176.

the former, but decisive evidence in proof of this has not often been observed. The best was found on the north side of a narrow gully, stretching W.N.W., which passes about 1530 yds. south-west of Totaig: here considerable masses of eclogite, some of them three or four yards broad, are seen in vertical section to be almost surrounded by a hornblende-epidote-schist, either with or without distinct garnets, the foliation planes of which are sometimes parallel to the edge of the adjacent mass of eclogite, while at other times they strike against this mass, becoming fainter and ultimately dying out as they are traced towards it. From the abundance of epidote and the comparative rarity of garnet in the hornblende-schist, it seems probable that the former mineral has to a considerable extent replaced the latter. It is noticed in the same locality that many of the masses of eclogite are crossed by veins, often about half an inch thick, which show no schistosity, and in which the pyroxene appears to have been replaced by dark hornblende. The veins are often nearly straight and parallel, but sometimes cross one another, and they can be traced almost up to the outer edges of the masses of eclogite in which they occur (Fig. 5).

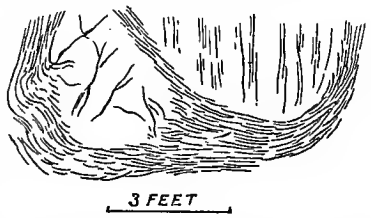


Fig. 5. — Portion of a vertical Scar with Eclogite. About 1530 yds. south-west of Totaig, Loch Duich. The eclogite is left plain white: the vertical lines in the right-hand portion and the irregular lines in the left-hand portion represent hornblendic veins which are not schistose. The areas indicated by the closely parallel curving lines are composed of hornblende-epidote-schist. Lewisian Gneiss.

Two-thirds of a mile E.N.E. of Sgiath Bheinn, a garnet-hornblende-felspar-rock (7689), which seems allied to eclogite, contains plates of lustrous graphite which are half an inch broad and slightly bent, and rather more than a third of a mile E.S.E. of the foot of Allt Tollaidh a hornblende-schist, close to a garnet-amphibolite, also contains distinct scales of graphite.

Near an exposure of eclogite and garnet-amphibolite rather more than half a mile slightly east of north of the Ordnance Station on Beinn a' Chapuill, a garnetiferous hornblende-schist contains kyanite (8448), and a mineral which resembles kyanite occurs in smaller quantity in the massive rock also.

In the cliff at the back of the raised beach 1033 yds. S.W. of Glenelg Established Church, a small patch of rock, only several yards in length and breadth, attracts attention from the striking contrast of its colours, parts being vivid green, others red and others again of a rusty tint. A specimen (7904) of this rock was found to be essentially composed of garnet and green chrome-mica (fuchsite): Dr. Teall regards it as an alteration form of an eclogite in the omphacite of which chromium was present.

Many of those hornblende-schists which are only seen far away from eclogite or garnet-amphibolite could not be distinguished from those which are closely associated with these rocks, and they are irregularly mixed with thin bands of acid gneiss, as the eclogite often is. For examples we may refer to the bands which have been mapped on the north side of the foot of Glenmore.

A garnetiferous hornblende-schist by the roadside a mile south-west of Ellanreoch presents a somewhat unusual type, in which the hornblende takes the form of small *augen*, and the garnets are edged with thin white rims of felspar.

In several places, *e.g.*, a third of a mile south-west of Knock Mill and near the north-west end of Eilean Rarsaidh (Loch Hourn), bands of hornblende-schist, hornblende-biotite-schist or hornblende-chlorite-schist, have been observed containing pieces, less than a pea, of a limpid untwinned felspar, probably albite, which includes portions of the other constituents of the schist. It must, therefore, be regarded as a later formed constituent, and is perhaps of approximately the same age as the spots of new felspar in the Moine rocks (see Chap. III.) and as the spears of black hornblende which are found both in the Lewisian Gneiss series and the Moine rocks.

In the Lewisian gneiss of Skye, in an extensive area east of the road between Isle Ornsay and the southern margin of the map, the commonest type of rock is a variety of hornblende-chlorite-schist or hornblende-biotite-schist, which is of a greenish or yellowish-green colour and disintegrates with great facility, giving rise to unusually smooth landscape features. Needles of black hornblende crossing the foliation planes are very abundant in certain localities.

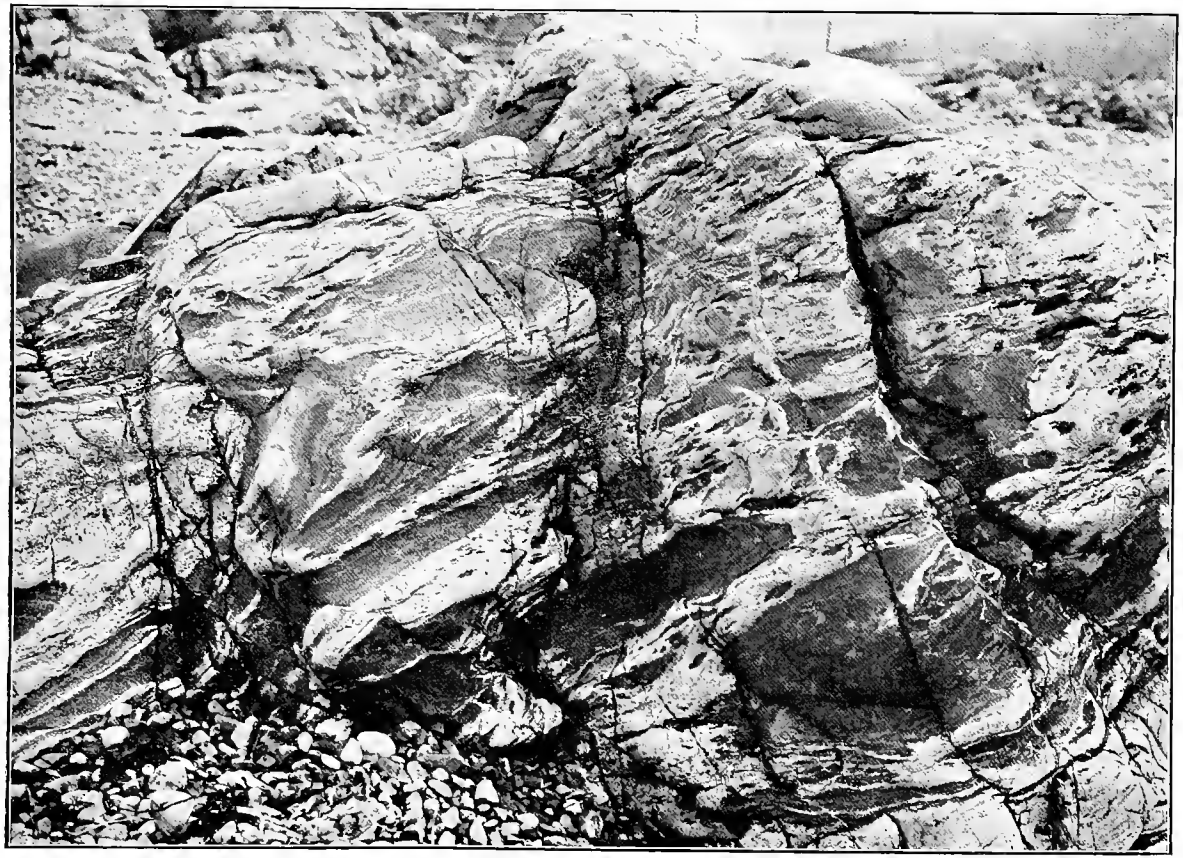
SERPENTINE, PYROXENITE AND OTHER ULTRABASIC ROCKS.

Ultrabasic rocks, especially those composed of hornblendite or biotite-hornblendite, are common in the form of small knots and lenticles in the more acid gneisses, but these are generally much too small to be shown on the published map. Bands composed chiefly of an impure serpentine with some admixture of pyroxene, etc., often attain larger dimensions, and a good many are shown, but the largest, which strikes in a north-east direction between Isle Ornsay and Knock (Island of Skye), probably represents an intrusion in the surrounding gneisses and schists, and is described in a subsequent section. Other smaller patches are shown in the following places: near Tigh Dhruid-eig, a third of a mile E.S.E. of the middle of Lochan an Beinne Faide, near the base of the Moine rocks near Bailamhuilinn on either side of Glenmore, S.S.W. of Loch Beinn a' Chaonich, a third of a mile north-east of Corrary, 300 yds. above the foot of Allt Mor (Gleann Beag) and in Allt Utha (east of Arnisdale).

All these weather with a brown or yellowish-brown crust, and most of them are mixed or edged with thin bands of talc schist, though in certain parts of the interior they are so massive that at first they might readily be mistaken for rocks which had been intruded after the great folds in the district were completed.

The exposure near Lochan an Beinne Faide somewhat resembles a big *augen* in form, being about 300 yds. long in the direction of the general strike of the neighbouring gneiss and 70 yds. broad, and it is swathed round at the south end by less massive gneisses. The common variety (represented by specimen 9330) is of the antigorite type, and it seems in a north-east direction to pass into pyroxenite.

The exposure a third of a mile north-east of Corrary is only about



HORNBLENDIC GNEISS INJECTED BY STREAKS OF PALE PINK FELSPATHIC GNEISS. Coast south-east of Creag Mhor, Glenelg Bay.

30 yds. wide. It is not well defined at the north and south extremities, but must run parallel to the adjoining gneisses. A specimen (7905) from this mass shows that the original rock was essentially composed of olivine and enstatite.

The exposures in Allt Utha, and some adjoining blocks which have slipped down from the hillside on the north-west, are of a very varied character, and contain in parts much talc together with needles of tremolite, also veins composed of steatite, and others of talc mixed with specks of ferriferous carbonate. A somewhat similar rock, with certain bands which are very rich in specks of ferriferous carbonate, is abundantly represented in the morainic drift on the east side of Rosdail, near the foot. On the coast near high-water mark at Rudha Mor (north side of the mouth of Loch Hourn) two big *augen* are included in the paler gneiss, one about five feet long and two broad, which are very calcareous throughout.

On the coast about 170 yds. slightly south of east of Rudha Mor, many of the dark knots consist mainly of hornblende or of hornblende mixed with a variable proportion of biotite. It is often noticed that several knots of one kind are found in close association, there being in one area a series which contains hardly any felspar, and in another a series in which this mineral is generally abundant.

Near the centre of Knock Bay, Skye, a hornblende-chlorite-schist (6765) seems to show the effects of pressure unusually well, some parts being massive and full of stout crystals of black hornblende, while other more flaggy parts are mainly composed of pale green actinolite needles with stouter black hornblendes scattered here and there. It contains also flakes of chlorite, of considerable size and sometimes bent, which include representatives both of the stout hornblende and the actinolite, and which must be of later formation than these. It is to be noted also that in this locality, and others not far away, the rocks contain crystals of iron pyrites which have had their corners ground off and their sides indented by parallel " slickens " along the foliation planes, while elsewhere these crystals show no clear deformation, but are edged by streaks of quartz and chlorite, extending in opposite directions. These directions vary a good deal in different places, but some are nearly east and west.

FELSPATHIC GNEISSES POOR IN FERROMAGNESIAN CONSTITUENTS.

Under this heading will be included certain gneisses which seem closely allied to the thin pink granulitic pegmatitic streaks of the Kirkton of Glenelg, already described in an earlier section, but which occur in considerable masses. They are usually of a pink colour but sometimes white, and the quartz and felspar, generally in a granulitic condition, form thin distinct subparallel folia or rods. Mica, whether in the form of muscovite or biotite, is usually scarce. The rock exposed on the shore between the mouth of Glenelg river and Creag Mhor is chiefly of this character, but is intricately mixed, as shown in Plate VI., with irregular lumps and bands of a much darker hornblendic rock into which it appears to have been injected. A considerable part of the Lewisian gneiss next the Moine rocks near the coast between the mouth of the Gleann Beag and An Gurraban is of a

similar character, excepting that it is more generally of a pink colour, and it is noteworthy that this variety of rock has supplied many of the pieces found in the supposed altered conglomerate at the edge of the Moine series (Chap. III.). In some localities it forms cliffs, 50 or 60 ft. high, which seem free from any other type of gneiss, and in the little burn rather more than a third of a mile slightly east of north of Mam an Fhuarain it forms most of the rock for a distance of 100 yds. east of the Moine series, though it is mixed in places with hornblende-schist into which again it appears to be injected in multitudes of thin inosculating veins. Further south-west, near Camas nan Alltan, it covers still more extensive areas, some of the outcrops being as much as 150 yds. broad.

In certain places the rock assumes a peculiar *facies* through the development of crowds of needles of dark actinolite which spear across the foliation planes of the rock, and sometimes attain a length of two inches. Excellent examples of these are seen close to considerable bands of hornblende-schist a little more than a quarter of a mile E.N.E. of An Gurraban, Sound of Sleat (Plate VII. Fig. 2), and both here and elsewhere they always appear free from any appreciable deformation, so that it seems likely they have been developed at the same time as the actinolites in the adjacent Moine rocks, and after nearly all the folding and shearing actions had ceased. Similar actinolites are also well seen in the island east of the Eilean Mor of Sandaig, in a cliff at the roadside half a mile S.S.W. of Glenelg pier, and many other places on the mainland. They are not confined to the gneisses of the type being described, but seem more conspicuous in them than in the others.

About 200 yds. south of An Gurraban the felspathic gneiss shows another variation in character, in consequence of the development of a number of thin seams which are chiefly composed of granular epidote mixed in unusually thin parallel laminæ with others of quartz. These laminæ have a very "thready" or sheared aspect, but are crossed by a number of flakes of black biotite which show no appreciable deformation, and which are probably of the same age as the actinolites referred to.

Actinolites and biotites of similar late development are also excellently seen in many parts of Skye, particularly between Isle Ornsay and Knock, where they have been described by Hugh Miller.*

In Skye, between Camas Croise and the coast three-quarters of a mile E.S.E. of Knock Mill, and on the north-west part of the Island of Ornsay, there are extensive exposures of a hard sharply jointed pink gneiss which is in places less granulitic than the type being described. Among the thickest bands are those at Ard Snusaich and on the headland three-quarters of a mile E.S.E. of Knock Mill, where it forms a cliff about 60 ft. high.

On the coast 170 yds. south of An Gurraban, a massive pink felspathic gneiss is crossed by a plane of discordance or thrust which strikes N.N.E. and inclines south-east, and the bands on the east side, where they are parallel with this plane, are very flaggy and show a faint sericitic lustre on their surfaces as well as close parallel lines resembling slickens. About 20 yds. further east,

* "Cruise of the Betsey," 8th ed. pp. 100–101.

FIG. 1.—FOLDED SEAM OF TREMOLITE. Limestone in the Lewisian Gneiss rather more than a mile east of Ardintoul, Loch Alsh.

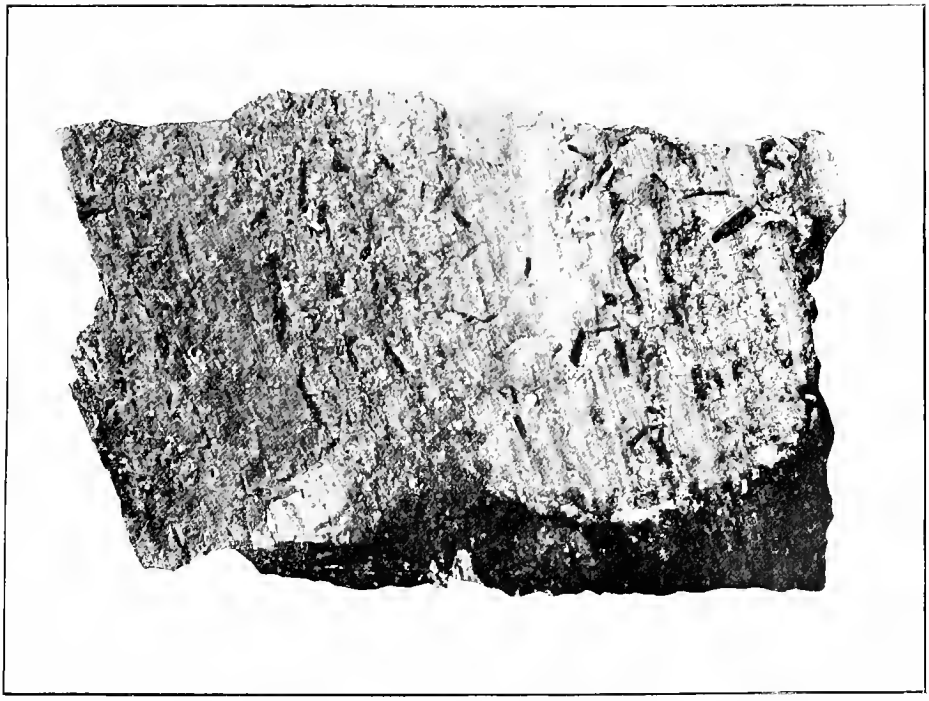
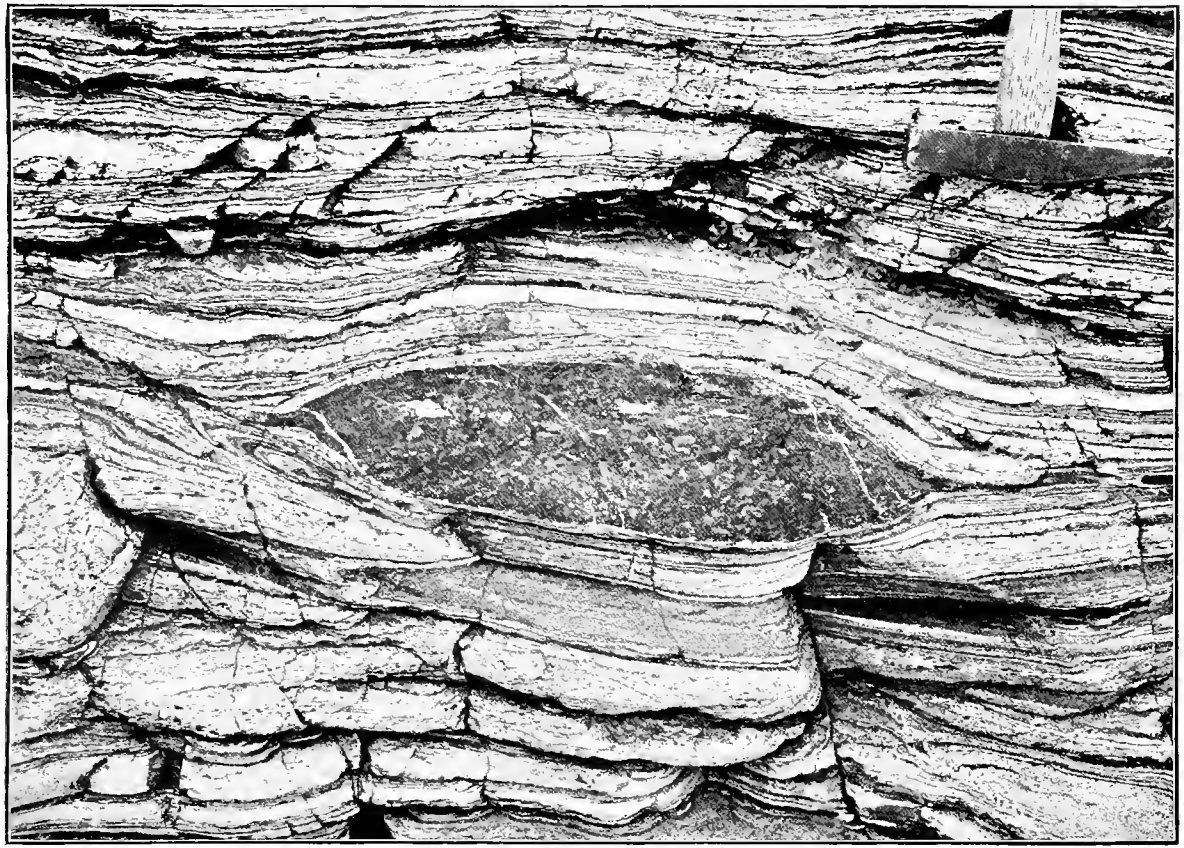


FIG. 2.—BANDED ACID GNEISS, WITH NEEDLES OF ACTINOLITE CROSSING THE BANDING. Rather more than a quarter of a mile E.N.E. of An Gurraban, Sound of Sleat.



THINLY BANDED HORNBLENDIC GNEISS, WITH BASIC LENTICLE NEAR THE CENTRE.
Coast near An Cleireach, Mouth of Loch Hourn.

another parallel sheared band, about a foot and a half thick, is again noticed with a sericitic lustre on the chief planes. It seems probable that these new shearing planes have been developed since the actinolites.

THINLY BANDED HORNBLENDIC GNEISS.

Thinly banded hornblendic gneiss, composed of pale grey or pinkish subparallel quartzo-felspathic granulitic laminæ separated by knots or lenticular laminæ of darker hornblendic material, forms one of the most wide-spread rocks in the district and one which especially helps to distinguish the Lewisian Gneiss series from that of the Moines. Folds with axial planes approximately parallel to the general direction of the banding are frequently seen. The alternating laminæ are often only a few inches thick, or even less, and we rarely see exposures more than a few feet broad which do not show a good development of hornblende in one layer or another, while in the adjacent Moine rocks this mineral is for the most part entirely wanting.

Rocks of this type are well seen close to the east side of the bridle-path (the "post-road") which leads from the Kirkton of Glenelg to Ardintoul (for half a mile or more on the south side of the county boundary), on either side of the Creag an Tairbh (south of Loch Alsh), near An Cléireach (see Plate VIII.), on the west side of Port an Tairbh (Loch Hourn), in the lower part of Allt Eas Mor Chul an Dùin (Gleann Beag) and many other places. They often contain a considerable quantity of epidote in small granules, which in places combine together to form streaks parallel to the foliation. Both the hornblende and the felspar in these epidotic rocks are often in a thoroughly fresh condition, and the granules cannot be regarded as products of their decomposition. The frequent alternation of bands of slightly different colour makes the isoclinal folding much more distinct than in many of the adjoining rocks, and it seems also probable that the very fact of the bands being thin may have made these rocks especially liable to give way to folding during crustal movements. Near Loch Coir' an Daimh (two and a half miles north-east of the Kirkton of Glenelg) the thinly banded gneisses show a strong second foliation, shown by parallel flakes of biotite which cross the first foliation at considerable angles, while the eclogites and amphibolites with which they are associated retain their massive character and may be without any foliation: the planes of the secondary foliation are often nearly horizontal. It is also seen in this locality that even the thin dark layers which form an integral part of the banded gneiss, and which may be only a few inches thick, are not so much affected by the second foliation as most of the paler layers; for, though the margins of the former are repeatedly wrinkled by minute folds, with axial planes parallel to the second foliation planes, the internal arrangement of their interior substance does not seem affected. In the same exposures excellent examples of a rodded structure (or linear foliation) may also be seen, the first foliation planes being divided into thin parallel stripes or rods by the minute folds referred to, or by accompanying strain-slips. Some of these thinly banded gneisses contain a notable proportion of magnetite, which is often in the form of octohedra, rather smaller than a pea. The darker laminæ, which contain

garnets, seem closely allied to the massive eclogites adjoining, and this banded series has apparently been produced by the close mixing of eclogite material in parallel layers with some other more acid substance.

It is to be remembered that in Sutherland somewhat similar banded gneisses are common, and that some of these have been developed by flow or shearing processes from more massive rocks which are probably of igneous origin. But in the Glenelg district it is suggested that the pale seams in some of the banded gneisses may represent altered sediments which have been intimately injected by thin sill-like layers of basic igneous rock. This is the impression conveyed for instance near Totaig, particularly by the burn section on the south side of the wood, where, as already mentioned in a preceding section, the paler seams are formed of a garnetiferous biotite-gneiss which in certain parts contains abundant kyanite.

On the west side of the Moine rocks of Beinn a' Chuirn there is a considerable area, unusually smooth and green in the landscape, which is composed of thinly banded hornblendic gneiss with a great proportion of soft readily disintegrating laminæ, in which the hornblende forms long needles lying on the foliation planes, but without any parallel orientation: flakes of biotite and small grains of epidote are also very abundant.

CERTAIN FOLIATED BASIC AND ULTRABASIC INTRUSIONS.

In this section a few representative bands which can be shown with tolerable clearness to be of intrusive origin, and which perhaps may be classed with the Scourie dykes of Sutherland, will be described in detail, but there are others, as may be seen on the north side of Loch Hourn near Eilean Rarsaidh and Glas Eilean, which also show some indications of such an origin, but less distinctly, in consequence perhaps of the greater amount of folding and deformation to which they have been subjected.* It is also possible, as already suggested, that there are still other rocks, not described in this section, which have been intruded under peculiar conditions which caused them originally to assume the forms of sills.

Only one band with any resemblance to those already referred to, has been observed in the Moine rocks in this one-inch map, though such dark bands would be more easily detected in these rocks than in the Lewisian gneisses, many of which are dark and hornblendic and not very different from the intrusions which cross them. It is evident, therefore, that the more abundant these intrusions can be proved to be, the more probable is the supposition that they are older than the original representatives of the Moine rocks.

On the west side of Eilean Mor (four miles south-west of the Kirkton of Glenelg), two thin bands of hornblende-biotite-schist (represented by 8662), from one foot to five feet thick, cut the banding of the gneiss at their sides at angles of about 45°, and have been traced

* To show how greatly the original relations of two rocks may he obscured by such actions, reference may be made to the pre-Torridonian anticline of Tollie, Poolewe, Ross-shire, in the centre of which the original intrusive character of the "Scourie dykes" is still quite distinct, while in the south-west limb we may search for long without finding any clear evidence of it. See "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, 1907, pp. 205–206.

in a south-east direction for a little distance. They are well foliated, usually parallel to the side.

On the adjoining coast, 100 yds. south of An Gurraban, a dark foliated rock, at least three or four feet thick, and consisting almost entirely of hornblende and biotite with a very little felspar (8663) cuts various hornblendic streaks and broad bands in the pink gneiss on its east side, and has been traced in a north and south direction for about 30 yds., its south end being a line of crush striking N.N.W. As a rule its foliation strikes against the side and in the same direction as the banding in the pink gneiss.

Across the island slightly south of east of Eilean Mor, a band of fine-grained hornblende-schist, eight or ten yards wide and of somewhat uniform character throughout, extends in an E.N.E. direction, nearly, but not exactly, parallel to the bands of the adjacent pale grey and pink gneiss. Its foliation strikes much the same as these bands, but its sides cut some of them at a small angle. Two pegmatites with a considerable amount of red felspar cross the hornblende-schist obliquely, and one of these, a foot and a half thick, is foliated in the same direction.

On the coast 230 yds. slightly west of north of the west end of Eilean Rarsaidh, there is a group of several thin vertical bands of hornblende-schist foliated parallel to their sides. These schists strike N.N.E. and distinctly cut the bands of a thinly banded hornblendic gneiss, though only at a small angle, as near the sides of the schists the bands of gneiss become more nearly parallel to these sides than they are further off, in consequence presumably of some special movement which has proceeded along the sides and induced the parallel foliation.

About 160 yds. E.N.E. of Glas Eilean (and about 50 yds. off the coast) a fine-grained band of hornblende-schist, one or two feet thick and foliated nearly parallel to the side, cuts the broad banding of the adjacent gneiss distinctly, the schist running W.N.W. while the gneiss dips east about 65°. The gneiss is to a large extent dark and hornblendic, but coarser in grain than the schist, and mixed with pale grey more acid bands quite unlike anything in the schist. It shows no clear second foliation parallel to that in the schist, but in one place is sheared along a plane parallel to the side of the schist and converted into a flaggy rock.

On the shore about 100 yds. south-east of the above exposures, there are two other thicker bands of a somewhat similar type of hornblende-schist, which generally strike N.N.E. and cut the adjacent gneiss here and there at a small angle, though they are folded and in places overlain by the gneiss.

The band mapped for more than a mile in a north-east direction between Knock and Camas Croise (Island of Skye) is somewhat too hard and impure (6769) to be regarded as normal serpentine. It is seen best on the west side of Loch Baravaig, where it forms three prominent hillocks,* and weathers with a buff or dirty yellow colour: the greatest width is about 60 yds. Most of the rock is massive, but some finely foliated varieties also occur. It contains a good many spots of ferriferous carbonate, and thin strings of this carbonate mixed with magnetite, a mineral which is also found in veins, some-

* On the top of one of which there is a Dun, not marked on the Ordnance map.

times six inches thick, as well as in thin laminæ running along the foliation and in scattered grains and clots. There are no good junction sections at the sides, but the relation of its outcrop to that of a folded band of hornblende-schist on the north-west side warrants the conclusion that it is of intrusive origin.

The W.N.W. side of the band of coarse garnetiferous hornblende-schist, striking E.N.E., on which Isle Ornsay Lighthouse stands, is well seen and runs nearly parallel with the adjacent gneiss; but on close examination it is observed that about 50 yds. north-east of the Lighthouse the bands of gneiss, which are here for the most part of acid composition but mixed with basic knots, are striking at a distance of a few feet off the side of the schist at a considerable angle to it, though as they come nearer they twist nearly into parallelism and become thinner, in the manner so often observed near the basic dykes of the Scourie district of Sutherland.

CERTAIN SPECIALLY CONTORTED BANDS, IN GREAT PART MICRO-GRANULITIC.

Various bands have been mapped, varying in composition in different parts, which agree in showing unusually striking evidence of contortion, and in being generally of distinctly finer grain than the neighbouring rocks of allied composition: the granules of their granulitic parts are, for instance, much smaller on the average than the granules of the neighbouring granulitic gneisses. These bands are not, however, very sharply defined from the neighbouring rocks, and though in places they cross the usual strike at a slight angle, they appear in these cases to represent altered forms of neighbouring rocks which have become modified under the influence of unusually sharp contortions. The widest band on the one-inch map being described is a little more than 100 yds. in width, but this is much wider than most.

Rocks of the character described are well seen in and near the burn rather more than a third of a mile south-east of Ardintoul (Loch Alsh), whence they can be traced E.N.E. about a mile: also in a locality a third of a mile N.N.E. of Glenelg School, from which they extend in one or more subparallel bands for several miles southward, as far as the big north-east fault which passes north-west of Ben Sgriol. Various other bands have also been traced near the east side of the broad outcrop of Lewisian gneiss which strikes north and south about a mile east of Arnisdale.

Nearly all these bands contain a considerable proportion of hard platy brown or grey schist which contains garnets as well as conspicuous *augen* of black hornblende and of felspar, and the matrix is so much finer in grain than that of the neighbouring rocks that it looks almost like a felstone. In a specimen (7927), collected from the exposure referred to near Glenelg School, it has been calculated that the average length of the granules in the micro-granulitic parts is about ·001 in., or about a fifth of that of the granules in the corresponding parts of a specimen (7914) from near Lochan Cul a' Mhoil, which was collected as a sample of the kind of rock from which 7927 was supposed to have been formed, and which may be called a garnet-hornblende-biotite granulite, with porphyritic hornblendes without

distinct idiomorphism. Under the microscope it is noticed that, in 7927, granules of quartz of much larger size than any in the matrix are occasionally included in the hornblende, or collected in little bays at its side, and it is suggested that these larger granules have been protected by their position from some of the movements which have affected the matrix and led to its fine granulitisation. If this suggestion is correct, the rocks described must be closely allied to mylonites, though they show no cataclastic structures. The intensity of the contortions which have affected the bands is very well shown on a microscopic scale in a specimen (7930) from one of the exposures near Ardintoul: the laminæ are repeatedly folded into isoclines and are pinched out at the side of the *augen*: it is clear that the appearances are not due to original fluxion, because flakes of biotite are sometimes arranged distinctly across the direction of the laminæ in which they occur, and parallel to the axial planes of fold.

On the west side of Meall Buidhe nearly all the paler acid bands which occur between the exposures of eclogite and massive hornblende-schist, etc., seem to have been specially altered and finely granulitised, giving rise to seams which resemble white saccharoid quartzite. One of these bands, a few feet thick, about 700 yds. northwest of the Ordnance Station 1594, is mixed with parallel greenish laminæ, about a quarter of an inch thick, which have been found by Mr. Barrow to contain an emerald-green biaxial chlorite, closely resembling one found by him in Glen Taitnaich, Glen Shee, Perthshire.

North of Loch Alsh and Loch Long.

East of the Moine displacement there is an important development of Lewisian gneiss, from one to three miles broad, which stretches from the upper part of Srath Ascaig in the north-east corner of the map, southwards across Gleann Udalain to the shore of Loch Alsh, west of the village of Dornie. Along its western margin there are infolds of crystalline schists belonging to the series of the Moine schists to be referred to in the sequel.

The prominent types of rock in this area are massive granulitic biotite-gneiss with basic knots and flaggy granulitic biotite-gneiss, sometimes garnetiferous, with thin bands of hornblende-schist. Some ultrabasic knots and lenticles have been detected in folds of acid biotite-gneiss in Allt Gleann Udalain, about a mile north of Nostie Bridge. In addition to these varieties, large irregular masses of basic igneous material, consisting of hornblende-rock or hornblende-schist, appear on the hilly ground round Beinn Conchra and Creag an Earbail, which recall the bands of early basic rock in the Fundamental Complex in the undisturbed area of Lewisian gneiss in the west of Ross-shire.

Round the infolds of Moine schist that occur within the Lewisian rocks of this area the granulitic biotite-gneiss with occasional knots and lenticles of hornblende-gneiss becomes more finely banded and has its planes of schistosity arranged more or less parallel with those found in the Moine schists. The best example of these platy granulitic rocks is found on the roadside east of the schoolhouse of Kirkton of Lochalsh. Eastwards on this road leading to Stromeferry,

the decomposing schist becomes less foliated till, at the bend overlooking the gorge of the Udalain, it consists of the coarsely foliated rock characteristic of this area.

The strike of the flaggy biotite-gneiss is generally N.N.E., and the dip of the divisional planes is E.S.E., but in the case of the massive biotite-gneiss and early basic rocks the strike is irregular. The direction of stretching is about W. 23° N.

An interesting feature is presented on the shore about a third of a mile east of the foot of Allt Gleann Udalain, where dyke-like bands of hornblende-rock traverse alike the acid biotite-gneiss and early basic material, like the epidiorite dykes in the gneiss of the western seaboard of Sutherland and Ross. B. N. P.

On the shore of Loch Alsh on the east side of the bay south from Kirkton of Lochalsh near the north-west headland of Avernish, some remarkable examples of pseudo-conglomeratic structure occur in the Lewisian gneiss. For nearly a third of a mile north from this headland there is a continuous shore section where the rocks consist of flaggy, fine and medium grained granulitic micaceous gneiss, hornblende-biotite-gneiss with bands of hornblende-biotite-schist and green chloritic schist, the strike being nearly north and south and the dip easterly. The rocks are repeated by inverted folds that die out along the strike, which are well seen at various points at the base and on the face of the cliff. The bands of green chlorite schist enclose phacoidal and oval masses of micaceous granulitic gneiss, hornblende-biotite-gneiss, hornblende-rock, and small rounded blocks of quartz. In some instances the gneiss lenticles measure from three to four feet in length, but these are exceptional, as the included blocks are usually of small size.

The deceptive resemblance to conglomerate has evidently been produced by mechanical movements, the several bands of gneiss having first been plicated and then subjected to still further crushing and shearing, whereby lenticular pieces of them were wrenched off and arranged with their long axes parallel with the foliation planes of the schist. These separated pieces are identical in character with the gneiss in which the hornblendic and chloritic schists lie. In the initial stages the thin banded gneiss has been sheared into phacoids which have been detached and intercalated as thin lenticles in the green schist (Plate IX. Fig. 1). But where considerable interstitial movement has taken place, the included blocks present subangular or rounded edges, and the matrix winds round the pseudo-pebbles (Plate IX. Fig 2). These phenomena may be studied at the base and lower part of the cliff about 500 yds. north from the south-west headland of Avernish (Plate IX.). J. H.

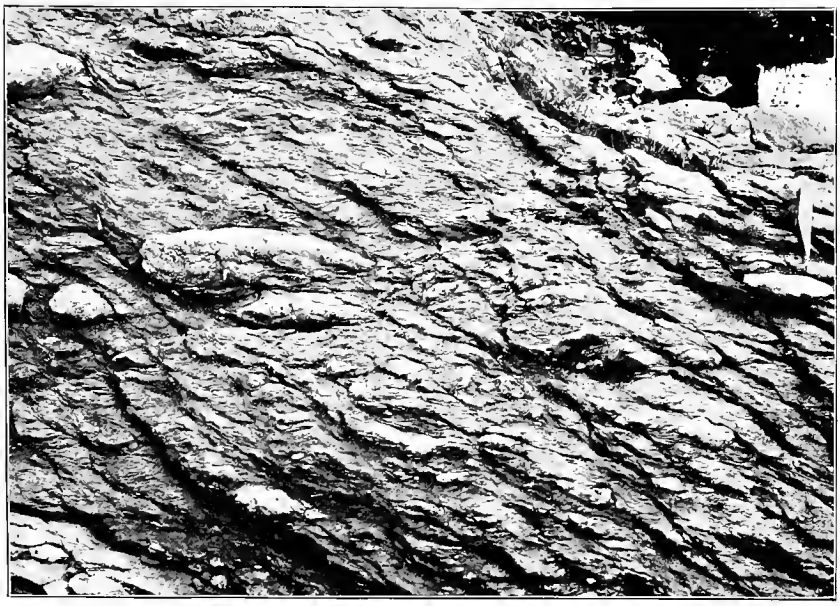


Fig. 1.—Initial Stage of Crush Conglomerate, with Thin Lenticles of Gneiss in Green Schist. East side of Bay of Kirkton of Lochalsh.

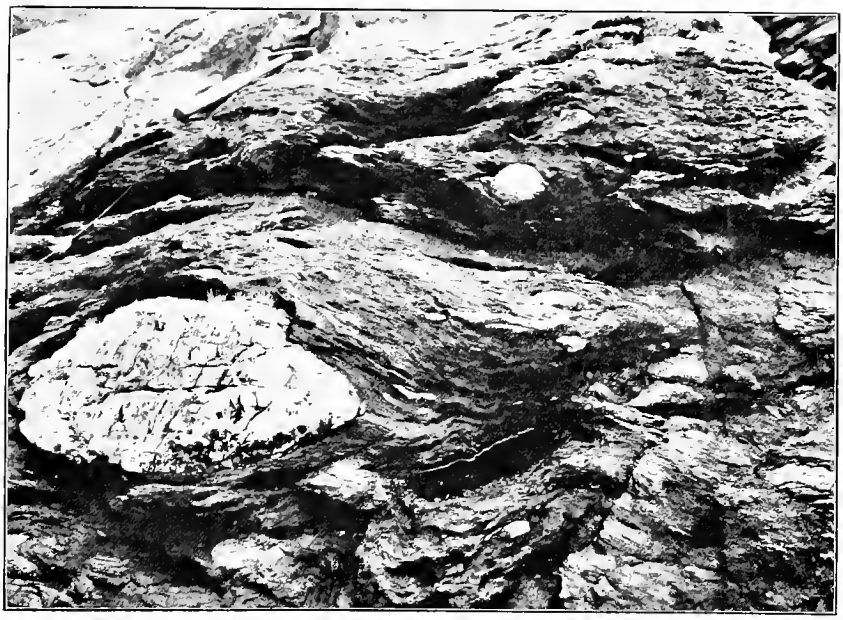


Fig. 2.—Crush Conglomerate, with Rounded and Subangular Blocks of Gneiss in Green Schist. East side of Bay of Kirkton of Lochalsh.

CHAPTER III.

METAMORPHIC ROCKS OF THE MOINE SERIES OR EASTERN SCHISTS.

Introduction.

The rocks of the Moine series are found in two districts, one north-west and the other south-east of the Moine thrust. In the former they only occur near Tarskavaig, where they compose a small area three or four square miles in extent, while in the latter they form perhaps half the country, being repeated again and again in bands which are most intimately mixed with the Lewisian Gneiss series. Nevertheless the Moine rocks near Tarskavaig, which together with some neighbouring rocks further south, in the one-inch map 61, may conveniently be called the Tarskavaig Moine rocks, are of special interest, because, though they clearly belong to the same great formation as the Moine rocks on the south-east side of the Moine thrust, they are yet in a decidedly less altered condition, and help to fill up the gap in degree of metamorphism between the most altered of those rocks which can with confidence be claimed as Torridonian and the more common types of Moine rocks.

The Tarskavaig Moines are much more altered than those Torridonian rocks which are found adjacent to them, but in certain districts, particularly on the south side of Loch Carron, the Torridonian rocks become nearly as much altered. The conclusion that the Tarskavaig Moines belong to the same great formation as the Moine rocks on the east side of the Moine thrust has been arrived at not so much in consequence of the degree of alteration they display, but because of the similarity in the stratigraphical sequence and the character of the supposed basal beds of these two sets of rocks, and of their similar relations to the Lewisian Gneiss series. These similarities may be seen by comparing the sections on the coast three-quarters of a mile north-west of Loch Nigheann Fhionnlaidh with those near Tormore and between this place and Meall Buidhe (one-inch map 61). In these sections there are no representatives of the epidotic conglomerates which always form the bottom zone of the Torridonian formation in Skye, and the altered sediments next the Lewisian Gneiss series are chiefly of a pelitic or semi-pelitic character, but mixed with many thin fine-grained siliceous bands and some calcareous pebbly seams.

It appears probable that all the Moine rocks once formed parts of an area in which the metamorphism increased in a south-east or east-south-east direction, and that the Tarskavaig thrust, which carried forward the Tarskavaig Moine rocks, has brought these rocks

a less distance from the east than the Moine thrust has brought the rocks which lie on it.

All the Moine rocks were probably isoclinally folded and altered, and nearly in the same condition as they are now, before the thrust took place, and there is evidence that their crystalline structure is to some extent broken down near the thrusts. But still the thrust must have been due to some great driving force originated further east, and it is natural to suppose that this force would first make itself felt by the production of isoclinal folds of the type so commonly found in the district. It seems reasonable, therefore, to imagine that the thrusts were not separated by any great interval of time from the period during which the folds, or at all events many of them, and the metamorphism of the Moine rocks were developed, and that consequently this metamorphism may be of post-Cambrian age.

As stated in Chap. IV., the alteration in the Torridonian rocks also increases in a south-east direction, where isoclinal folds are found, so that it is not always easy to distinguish the Tarskavaig Moine rocks from them. In 1892 Dr. Peach, in describing the results of his examination of the area south of Loch Carron, stated that the Moine schists of that area appeared to be altered Torridon sandstone which had been caught and enclosed within a great synclinal fold by a mass of Lewisian gneiss as it was driven westward.* There is no doubt that the unaltered representatives of a great part of the Tarskavaig Moine series must have had considerable resemblance to the Diabaig rocks of the Torridonian formation: they must have formed a thick sedimentary formation composed chiefly of false-bedded grits or sandstones, together with groups of sandy shales and occasional thin calcareous lenticles: some of the shaly seams are of a peculiar character also, and contain small pebbles, just as some of the shales in the Loch na Dal series do.

Beds which could represent the epidotic grits and conglomerates at the base of the Diabaig division are, however, rarely found in the Moines, and the great bulk of the siliceous Moine rocks seem more siliceous than the grits of the common Diabaig type. It must be remembered that the Moine rocks have all been pushed forward from areas further east than the recognisable Torridonian have, and it is possible that the Torridonian rocks deposited in these eastern areas may originally have differed considerably from those further west. On the other hand, the Moine rocks retain much the same characters all the way from Loch Eiriboll to Skye—a distance of more than 100 miles—in spite of the great variations of the Torridonian rocks in the west. In view of this fact and of the great number of quartzite pebbles in some of the Torridonian rocks, we feel that the evidence at present available does not warrant the conclusion that the Moine rocks represent Torridonian rocks. They may do so, but this remains to be proved.

The general relations between the Moine series and the Lewisian Gneiss have been described in connection with the latter, and it has been concluded that the latter is younger than and unconformable to the former, though the unconformity is not now very striking. It is necessary to say, however, that just as different types of Lewisian

* *Annual Report of the Geological Survey* for 1892, p. 262.

gneiss can be found in contact with Moine rocks, so also can different types of the latter with Lewisian gneiss rocks, the impression conveyed being that the original representatives of the Moines have occasionally overlapped one another, or have been deposited against banks or hills formed by the Lewisian Gneiss series.

In respect to character, most of the Moine rocks are divisible into three types, as follows :—

1. Pelitic rocks, including phyllites and the more micaceous schists and gneisses, which are believed to represent sandy shales in various stages of alteration : the more purely argillaceous sediments appear to have been rare.
2. Psammitic rocks, including schistose grits, granulites and the paler, more siliceous schists and gneisses, representing grits, etc., in different degrees of alteration.
3. Conglomeratic rocks, represented by a schist which occurs next to the Lewisian Gneiss series in one district only.

Rocks which possess characters intermediate between those of types 1 and 2 are sometimes found, and also bands which are composed of very thin alternations of these two types ; but these rocks and bands do not make large areas and they have been mapped with the adjoining larger masses.

In many places, particularly near Tarskavaig, the rocks which come against the Lewisian Gneiss series are chiefly of pelitic type, and, at the other side of these, great exposures of psammitic rocks are often found. On the south-east side of the Moine thrust, however, we usually find next the gneiss a considerable thickness of psammitic rocks which are no doubt on the same horizon as the other psammitic rocks just referred to. Much the greatest areas composed of pelitic rocks lie on the south side of Loch Hourn, but these are not very near any exposure of the Lewisian Gneiss series, and are perhaps higher in stratigraphical horizon than the pelitic bands which are elsewhere found next this series.

On the south-east side of the Moine thrust there is evidence in various places that after the Moine schists had been folded into isoclines they were subjected to renewed movements, which had the effect of crumpling the limbs of these isoclines. Such evidence is seen, for instance, on the north side of Eilean Tioram, Arnisdale, and by the roadside a little further north, near Camas Driseach. In the first-named locality the limbs of the isoclines generally dip steeply W.N.W., but they are affected by a close set of wrinkles, with axial planes inclining east about 20° or 30°, which also crumple various quartz veins and thin pegmatites. In this one-inch map it is somewhat unusual to see in the Moine schists isoclines with axial planes inclining westward, and perhaps the phenomena here observed are due to folding of isoclines which once dipped eastward. What amount of interval elapsed between the two movements indicated is not known, but it seems possible that during it the partially schistose basic band, described in Chap. VII., may have been intruded.* C. T. C.

* See W. B. Wright's paper, "On the Two Earth-Movements of Colonsay," *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv. p. 297.

Section I.—Area North-West of the Moine Thrust.

SLEAT.

The Moine rocks to be described, comprising part of the Tarskavaig Moine series, lie on the Tarskavaig thrust, which has been folded into a syncline with axial plane inclining E.S.E., and they are associated with smaller exposures of highly sheared rocks which are referred to the Lewisian Gneiss series, and which generally form a rim between them and the outcrop of the thrust.

In most places the Tarskavaig Moine beds which come next this rim chiefly consist of phyllite mixed with some fine-grained siliceous schists, making together a band which is seldom so much as 50 yds. broad. Above this comes an alternating series, in which the siliceous beds, though in considerable excess of the phyllites, are finer grained and paler than most of the still higher schistose grits. Considerable exposures of phyllite are found in some places, *e.g.*, near Loch Nigheann Fhionnlaidh and on the north-east side of Sgurr Breac, which are not near any exposure of the Lewisian gneiss, and it is uncertain whether they belong to the horizon of the phyllites already mentioned at the beginning of this paragraph or not.

The general dip of the beds near the western outcrop of the thrust is south-east or east-south-east, often about 30° or 40°, but it is probable that this frequently represents the dip of isoclinal folds. On the east side the thrust is sometimes vertical or even reversed, and so also are the Moine rocks.

The phyllites vary in lustre in different localities, but the flakes of white mica to which this lustre is due are never large enough to be individualised by the naked eye. The phyllitic material is always mixed with thin sandy or gritty streaks, and occasionally also, as for instance rather more than two-thirds of a mile N.N.W. of Cnoc a' Gharbh-uillt, with thin calcareous seams containing clastic grains (7347). Biotite has not been observed within this one-inch map, but a little further south, in one-inch map 61, it is tolerably common in little spots.

The schistose grits which come above the phyllites next the gneiss make up the larger part of the area, and are probably of great thickness. They are excellently exposed at the coast near the south margin of the map, and also in numberless inland crags. The average size of the remains of the larger clastic grains varies band by band, so also does the relative proportion of the quartz and felspar grains, and these variations bring out very well the bedding and false-bedding. The general size of the granules of the granulitic matrix, and of the associated flakes of white mica, is much less than that of the corresponding elements in the Moine rocks which lie south-east of the Moine thrust. Many of the pebbles of quartz are in a greatly deformed condition, being stretched out into long parallel streaks which are occasionally as much as two or three inches long (half a mile south-east of the east side of Loch Gauscavaig), and it is noticeable that a blue opalescent tint may be retained even in those which are greatly stretched. The felspar pebbles are generally red, and a good proportion of them appear to consist of microcline. They are generally much less deformed than those of quartz, and we can often see that

the whole breadth of a pebble is occupied by one cleavage plane, while the neighbouring quartz pebbles are all represented by long parallel streaks. Small grains of epidote are common and sometimes so large and abundant that they can be recognised by the unaided eye.

Short thin veins, rarely more than an inch or two thick, composed of quartz with a small proportion of red felspar, chlorite and occasionally some carbonate, are tolerably common both in the phyllites and schistose grits, and may probably be regarded as segregation veins. In specimen 7354, from the coast about 150 yds. within the adjoining map 61, the felspar was determined by Dr. Teall to consist of albite or an allied species.

Section II.—Area South-East of the Moine Thrust.

SOUTH OF LOCH ALSH.

In this area the Moine schists are found both on the mainland and on the Island of Skye, but in the latter they are confined to small stripes near the Moine thrust, near Camas a' Mhuilt and Allt Bealach na Coise, and to a small folded patch, with a faulted western boundary, on the north side of Camas Croise. On the mainland they make much more extensive tracts, many of them in the form of subparallel belts intimately mixed with the Lewisian Gneiss series, the two sets of rocks being repeated again and again by isoclinal folds with axial planes generally inclining south-east. But in other places these folds have been cut by powerful later faults, as on the north-east side of Glenelg Bay and between Beinn a' Chapuill and Ben Sgriol, which have interfered with the general uniformity of arrangement.

In that part of the mainland which lies between Loch Alsh and Loch Hourn, the psammitic beds are in great excess of the pelitic, and it is these which make the highest and roughest hills, such as Beinn a' Chuirn, Beinn a' Chapuill (*see* Frontispiece) and Ben Sgriol. On the south side of Loch Hourn, almost the whole area, with the exception of a small patch of Lewisian gneiss near Rudh' Ard Slisneach, is composed of Moine rocks, and the pelitic or semi-pelitic varieties are nearly as widespread as the psammitic.

In certain localities the boundary lines between the Moine rocks and the Lewisian gneiss can be followed almost straight for long distances, and we can see that in different places different types of Moine rocks come up against the gneiss; thus on the eastern side of the Moine band which runs southward from a locality about half a mile E.S.E. of Ellanreoch, the marginal Moine rock at the north end is a siliceous schist, a little further south a thin pelitic schist comes in between this siliceous schist and the Lewisian gneiss, and still further south, near Loch a' Ghleannain, this pelitic schist dies out again.

The eastern slope of Beinn Aoidhdailean, in the adjoining one-inch map 72, but less than a mile from the western edge of the map being described, shows two different types of Moine rocks in contact with opposite sides of a thin band of the Lewisian Gneiss series. The band is only about 100 yds. wide and is bounded on the west side by rocks which are mostly of pelitic character, while on the east,

for about a mile along the strike, there is a belt of unusually siliceous schist. The difference in the beds at either side seems startling, but we must remember that the fold in which we suppose the Lewisian gneiss to occur may have very long limbs, and that the present distance between the two beds may be considerably less than that which separated their areas of deposition.

The Moine tract between Port a' Gharàidh and the Sandaig Islands, on the south-west side of the Sound of Sleat, is of special interest, because along a considerable part of its south-east margin we find a boulder-bed or conglomerate-schist, which not only crosses the broad banding of the adjacent Lewisian gneiss, but encloses also pebbles and boulders which have in all probability been derived from this gneiss. The dip in this tract is south-east, often at angles between 35° and 50°, and the conglomerate-schist is now the topmost bed of the Moine series, and is overlaid by the Lewisian gneiss, of fragments of which we suppose it to be partly made up; but the present positions are, of course, due to folding and do not indicate the original relations.

The conglomerate-schist varies in thickness and character from place to place, but it is not generally more than 20 or 30 ft. thick, and in some places, even between localities where it is well developed, it seems hardly represented. The best exposures are along the outcrop between the localities a third of a mile north and rather more than two-thirds of a mile south-west of Mam an Fhuarain, but it is seen again rather more than a mile south-west of this hill, and still further on, as far as Eilean Mor.

The matrix usually contains many large flakes of black or brown biotite, lying nearly along the foliation but a good deal waved or crumpled, together with granules or short prisms of epidote in considerable abundance. In some localities, for instance, rather more than a third of a mile south-west of Mam an Fhuarain, black hornblende also occurs in abundance, and small garnets are found (8645). Where the hornblende is present, it is partly in long needles and partly in stouter forms, and the former at least are probably of secondary origin and of the same age as the long spears of actinolite which occur in crowds in certain beds of the pelitic Moines in the near neighbourhood.*

In the locality rather more than a third of a mile south-west of Mam an Fhuarain, the bed includes, besides the hornblende in the matrix, many large dark hornblendic lenticles, closely packed and some of them several feet long, which appear to represent boulders derived from the adjacent hornblende-schists in the Lewisian gneiss, though in the exposures north of Mam an Fhuarain no hornblende has been noticed in the conglomerate-schist, either in the matrix or the pebbles.

The smaller pebbles seem mostly composed of quartz or of red felspar, which is often striated; but many of the larger, giving cross sections more than half an inch broad and an inch long, are composed of a composite foliated rock with a considerable resemblance to the pink felspathic bands in the adjacent Lewisian gneiss, though usually in a less sheared condition than these, presumably in consequence

* As, for instance, a few feet below the conglomerate-schists in the locality last mentioned, and on the coast north-west of An Gurraban.

SUPPOSED CONGLOMERATE SCHIST. Nearly half a mile W.S.W. of Mam an Fhuarain. The large white patch near the centre is perhaps a portion of a quartz vein.

of the matrix of the conglomerate-schist having acted as a soft cushion which protected the pebbles to some extent from deformation. Lenticles of an allied foliated rock, in which the felspathic parts have been partly or wholly replaced by epidote, are also common. The lenticles are frequently quite distinct in outline and almost oval in shape, with the lesser diameter varying from one to two inches in length and the greater from three to eight. They are often distributed somewhat sporadically, each large specimen being separated by considerable spaces from any other of the same kind, so that it is impossible to regard them as portions of a former continuous band which have been nipped off by folding and strain-slipping. In Plate VII. the supposed pebbles seem more numerous than usual. Many of the quartz pieces in the bed are in the form of long parallel rods, drawn out in the same direction * as the particles of the overlying Lewisian gneiss, and in some cases they are so much longer than broad that we hesitate to say whether they represent pebbles or quartz veins.

As we descend the hill slope below the conglomerate-schist, this bed is seen in places to pass into a biotite-schist which is more pebbly than the common types of Moine schists, and this again gives place to more normal pelitic schists. The exposures are sufficiently continuous to make it clear that the conglomerate-schist is not separated by a distinct thrust, either from the Lewisian gneiss above or from the other Moine schists below.

The pelitic band below the conglomerate-schist varies considerably in thickness. On the coast near Port a' Ghàraidh it is perhaps 30 ft., and at its south-west extremity, near An Gurraban, it is probably more than twice as much, but includes many thin bands of siliceous material. Flakes of biotite and muscovite are generally abundant along the foliation planes, and in certain places flakes of the former mineral also cross these planes. Pink garnets, about the size of peas, are abundant both in the psammitic and pelitic layers, and long needles or blades of actinolite are also common in certain siliceous bands. On the coast, a little north-west of An Gurraban, there are also a good many micaceous seams which contain numerous spots, often about the size of a pea, which Mr. Bailey has examined and finds to consist of potash felspar, sometimes showing the structure of microcline. These spots have suffered no appreciable deformation or granulitisation, and must be of secondary origin. It should be stated that in the area north of Loch Hourn, those pelitic beds which occur so far north-east as the band just described do not, as a rule, contain distinct spots of secondary felspar, nor distinct actinolites; in the bands, for instance, which run southward from Garbhan Cosach (represented by specimen 7894) and close past Ellanreoch, neither of these minerals seems to occur, though garnets and flakes of black and brown mica are abundant.

In the bands two or three miles further south-east, as, for instance, the thin band mapped near Loch Beinn a' Chaoinich, the band passing rather more than half a mile south of Balvraid, and the thicker bands east of Strathchomair, the structure is generally coarser than in the north-western bands, the flakes of biotite and white mica are larger and less parallel and so mixed with *augen* of felspar and thin

* Usually nearly parallel to that of the dip of the foliation.

quartzo-felspathic or pegmatitic streaks that in places half the rock consists of them. There seems, indeed, a tendency for the pelitic beds to become more pegmatised than the neighbouring psammitic rocks. Garnets of violet or pink colour are also usually abundant. In the bands on the north side of Loch Hourn, hornblende has not generally been observed, but it occurs in some thin bands a little east of Arnisdale, which probably belong to the basal part of the Moine series.

The pelitic exposures on the south side of Loch Hourn differ somewhat from those on the north. The beds near Eilean a' Mhuineil extend south into the one-inch map 61, and, with similar strata, form the mountain of Ladhar Bheinn, from which all these beds may be called the Ladhar Bheinn beds. At the present ground surface they are underlain on both sides by siliceous schists, but perhaps they occupy the central portion of a great fan-shaped fold. The more micaceous beds are usually very coarse or gneissose in structure, containing big flakes of black and white mica divided by scattered garnets and by granules and streaks of quartz and felspar. These beds, which generally give rise to very blocky scars or somewhat green slopes, are mixed with other more siliceous bands of two different types, one without garnets and sometimes as much as 30 or 40 ft. thick, and the other much thinner, rarely exceeding four or five inches, and lenticular, and containing zoisite, garnet and needles of hornblende which frequently spear across the foliation. The last-mentioned seams are parallel to the bedding, and perhaps represent layers which were originally slightly calcareous. They are, no doubt, of much the same character as those previously described by Mr. Gunn and Dr. Teall in the biotite-schist of the Moine series in one-inch map 92.* Similar layers have also now been found in the pelitic beds of the Moine series in many other parts of the Highlands. In the micaceous beds 150 yds. south-east of Eilean a' Mhuineil, needles of tourmaline, occasionally an inch long and somewhat bent or broken, are tolerably abundant, but they are not generally common elsewhere.

The Ladhar Bheinn schists are separated from the siliceous schists which appear to underlie them by a passage zone, often from 50 to 100 yds. wide, composed of thin alternating beds, some of siliceous and others of more micaceous character, many of which are no more than an inch or two thick. On the published map the zone is represented by a wash of the pelitic colour on the outer margin, the interior portion being left pale crimson lake.

On the coast about a mile north-west of the Ladhar Bheinn beds, we find another broad band, which may be called the Rudha Ruadh band, which is also somewhat pelitic but generally rather less so and also less coarse in structure than the Ladhar Bheinn beds. This band is finely bedded, and contains many thin micaceous seams which are crowded with small spots, the size of shot or small peas, composed of secondary micropoikilitic potash felspar, sometimes showing the structure of microcline. Spots of secondary felspar also occur near the passage zone at the margin of the Ladhar Bheinn beds, and it seems possible that the Rudha Ruadh series represents certain of the Ladhar Bheinn beds together with some adjoining rocks. None of the peculiar thin seams containing zoisite and hornblende have yet been noticed in the Rudha Ruadh beds; but as these

* *Summary of Progress of the Geological Survey* for 1897, p. 41.

beds are traced southward, into the one-inch map 61, they become coarser in structure and indistinguishable from many of the more micaceous beds of the Ladhar Bheinn exposures.

Spots of secondary feslpar, which in their mode of occurrence and macroscopic aspect closely resemble those in the Rudha Ruadh beds, are also abundant in various beds which occur on or near the coast between Rudha Ard Slisneach and Airor, and some of these spots (9852, from 150 yds. east of Eilean Aigastan) have been found to consist of alkali felspar containing both soda and potash. It is noteworthy that these spots are most abundant in the micaceous seams. Examples are not uncommon in the semi-siliceous bands, but never seem to occur in the purer siliceous rocks.

Near Airor there is a considerable area composed of finely banded, mostly rather pelitic, schists bounded on the east by a powerful fault. The micaceous beds are less coarse in structure than the Ladhar Bheinn beds, and contain few or no pegmatitic streaks, but many garnets and in certain bands a good number of spots of secondary felspar. Impure calcareous lenticles and thin seams, rarely more than a few inches thick, are common, and in the adjoining one-inch map 61 some of these seams contain clastic grains, chiefly of quartz, which are more than half an inch long.

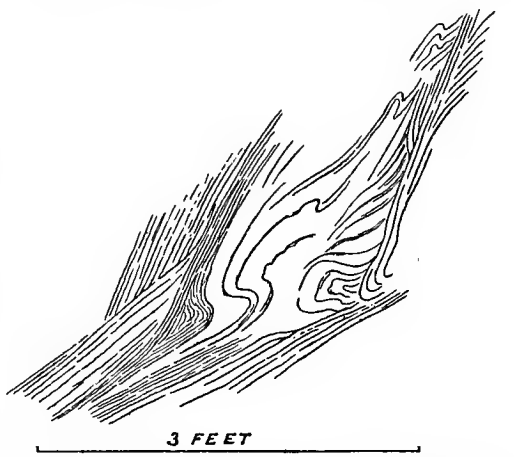


Fig. 6.—False-Bedding in the Psammitic Schists of the Moine Series. From vertical scar a mile and a quarter south of Beinn na Caillich, south of Loch Hourn.

Those psammitic beds which are found in the north-western part of the area are well represented in the typical sharply-jointed crags west and south of Bernera and on the coast near Rudha na h' Airde Beithe and Camas nan Alltan. In these last localities the old bedding planes are quite distinct, and so also are the minor irregular laminæ which bring out the false-bedded character. Remains of many clastic grains are also recognisable, and consist chiefly of red felspar and quartz, which is often slightly opalescent. Some thin laminæ are dark grey from the abundance of magnetite or in other cases of ilmenite, and though these minerals mould or include other constituents of the rock (as in 7893, from near Bernera, and in 9119, from near Rudha an Daraich), there can be little doubt that they represent recrystallised clastic grains, for they occur along the bedding and are intimately mixed with the other minerals which are usually found in the heavy sediments in other geological formations. In some places, but perhaps particularly near Beinn na Caillich (south side of Loch Hourn), the laminæ composing the false-bedded bands seem to have been

arranged in sharp curves before the bands themselves were folded (Fig. 6).*

A specimen (7680) of a siliceous flagstone was collected near Bernera as a type of the psammitic beds, and this has been analysed by Dr. Teall, to compare with a specimen of the Beinn na Seamraig grit (Torridonian) from a little further west. The analysis is given below, and it will be seen on comparing it with the analysis of the other specimen (Chap. IV.) that in the Moine rock there is 8·64 per cent. more silica than in the Torridonian grit, and that the proportion of potash to soda is considerably greater.

SiO_2	82·2
Al_2O_3	9·16
Fe_2O_3	1·8
CaO	·8
MgO..	trace
K_2O	3·04
Na_2O	1·75
Loss on ignition	·84
	99·59

A few miles south-east of the Sound of Sleat, as, for instance, on Beinn a' Chuirn, Beinn a' Chaonich, the south-eastern side of Beinn a' Chapuill and the western slopes of A' Chrannag, the psammitic beds are usually much coarser in grain, and also much more mixed with thin pegmatitic veins and lenses, than their congeners near Bernera and Rudha na h' Airde Beithe, which are almost free from similar pegmatites, though they contain thin veins of quartz mixed with a small proportion of felspar. Plate X. shows the abundance of these veins in the western slopes of A' Chrannag. In the south-eastern bands the average size, both of the granules of the granulitic mosaic and also of the mica flakes, is indeed so great, that some experienced observers have on first examination refused to correlate the two sets of beds.

Some beds in the burn about 240 yds. north-east of Achadhachuirn are unusually rich in biotite, and are mixed with other beds of a semi-siliceous character. This group of beds of intermediate character has not been separated in the map from the great mass of more siliceous beds further north-west, but it seems probable that they come above them in stratigraphical position. Beds of an intermediate character, which may also be in the same horizon as the above, cover a considerable area near the top of Beinn a' Chuirn, a little south-east of the Ordnance Station.

In Allt Bealach na Coise, about two miles slightly south of west of Isle Ornsay, a band of Moine schist immediately overlying the Moine thrust is broken along a close series of thin crush lines, the general direction of which appears to agree with that of the thrust, and on the coast about a quarter of a mile south of Rudha na h' Airde Beithe there is a thin band, highly fissile along parallel planes, which strikes N.N.E. and inclines E.S.E. This crosses the bedding of the siliceous schists at a slight angle, but its margins are not sharply

* It has long been known that in some unaltered sediments, but perhaps particularly in the Torridonian grits, the minor laminæ are often sharply curved even when the bands which they compose are nearly horizontal (see Chap. IV.).

PSAMMITIC GNEISS OF THE MOINE SERIES. Of the coarse-grained type and full of felspathic spots and streaks which are often difficult to distinguish from the matrix. Western slope of A' Chrannag, four and a half miles south-east of the Kirkton of Glenelg.

defined, and it has apparently been formed from the schists by a shearing process. The fissile planes are parallel to the general direction of the band; their surfaces are much smoother than those of the foliation planes in the common types of Moine schist, and are marked by close lines of movement, resembling slickens, parallel with the direction of dip.

NORTH OF LOCH ALSH.

Between Kirkton and Auchtertyre Hills north from Kirkton of Lochalsh, there is a narrow belt of Moine or Eastern schists, about 300 yds. broad, overlying the Moine thrust-plane. These consist of flaggy siliceous schists or quartz-biotite-granulites with thin partings of biotite-schist, which dip to the east or a few degrees to the north of east, and are well exposed in the Auchtertyre Burn. Near the source of this stream, and also near the head of the rivulet that flows north-east towards Gleann Udalain, where the Moine schists have been puckered and driven over the thrust flaser gneiss of Kirkton Hill, there is evidence of the breaking down of the structures of the siliceous schists. Along the eastern margin of this belt and west of the top of Auchtertyre Hill, the junction line is visible between the quartz-biotite-granulites and the rocks which have been grouped with the Lewisian complex. A traverse along this line shows that the Moine schists come successively in contact with different members of the Lewisian complex. J. H.

The strip of Moine schists just referred to has been traced northwards from Gleann Udalain to Braeintra in Srath Ascaig, where the rocks present similar lithological characters. Along the western margin of this belt the Moine displacement has brought siliceous schist into contact with thrust flaser gneiss. It is worthy of note that, in certain places within this strip, some of the clastic characters of the Moine schists are still retained, as, for instance, at the waterfall in the stream three-quarters of a mile S.S.E. of Braeintra and on the east slope of Carn Fada.

South of Braeintra there is a small outlier of the quartzose flagstones to the west of the main outcrop of the Moine thrust-plane, and within the area occupied by the displaced flaser gneiss.

East of the narrow belt of siliceous schists just described towards Glen Udalain, there are several infolds of Moine schists between bands of Lewisian gneiss, which show evidence of increasing metamorphism on each successive fold. The altered sediments (Moine schists) become more coarsely crystalline eastwards, and the intervening belts of gneiss are almost wholly granulitised. Of these, the most important is the one that runs northwards along the west slope of Meall Ailein to Allt Cadh' an Eas in Srath Ascaig. Along the eastern limit of this belt there is a band of garnetiferous muscovite-biotite-schist or pelitic gneiss which is well seen on Meall Ailein.

Even in the most easterly of these infolds, some of the schistose bands exposed on the northern slopes of Meall Ailein show to the naked eye that they have been coarse-grained arkoses. It is observable, however, that the only grains that have escaped total granulitisation consist of pink felspar up to a quarter of an inch diameter.

The feature of special interest connected with these infolds of

Moine schist, is the remarkable conglomeratic rock that may possibly mark the base of the series, which is exposed in two places about a mile and a half south of Braeintra. The first of these lies on the east margin of a narrow belt of siliceous schist, about 300 yds. west of the main road and a mile and a half south of Braeintra, where it forms an isolated knob peering through drift. The second exposure is visible about 100 yds. further to the east in a knoll, where the conglomerate rests on granulitic hornblende-biotite-gneiss, and passes eastwards underneath the Moine schist. In both cases the matrix is holocrystalline, composed of quartz, felspar, hornblende, biotite, muscovite and epidote, and enclosing fragments of granulitic gneiss and quartz. It is noticeable that the crystals of actinolite in the matrix pass into the included pebbles.

Two miles south of Braeintra, along the south-east slope of Beinn Raimh, the Moine thrust-plane is folded back on itself along a line of compression or sharp plication, the axis of which runs N.N.W. and S.S.E. The underlying mylonised Lewisian gneiss shares in this fold, and the plane of the Moine thrust is highly inclined on either side. About 300 yds. to the west of this plication, the Moine thrust-plane is well seen in a stream where it dips to the south at a gentle angle.

B. N. P.

CHAPTER IV.

TORRIDON SANDSTONE.

The Torridon Sandstone is well represented, and forms a broad band stretching in a S.S.W. direction right across the map, from near the north-east corner to the southern margin. It also forms most of the Island of Scalpa, parts of Skye south of Loch Sligachan, small portions of Raasay and Strathaird and the Crowlin Islands.

As in other districts, the formation is divisible into three great groups, which are as follows, beginning with the highest:—

3. Aultbea group. Reddish and grey fine-grained sandstones, with occasional bands of shale.

2. Applecross group. Red and chocolate-coloured arkoses.

1. Diabaig group. Red and grey grits and sandy shales, with basal conglomerate.

In this one-inch map the Aultbea group has only been recognised with confidence in the Crowlin Islands.

In describing the detailed character of the beds in different districts we shall first deal with the area south of Broadford Bay and Loch Alsh, as it is in this that both the Applecross and Diabaig groups are best developed.

Section I.—Area South of Broadford Bay and Loch Alsh.

INTRODUCTION.

The Torridonian rocks compose most of the south-eastern peninsula of Skye, a thin stripe on the mainland east of Kyle Rhea, and a small tract on the flanks of Ben Suardal, which is divided from the rest by Mesozoic rocks. They have all been thrust forward from the south-east by the great post-Cambrian movements, but most of them are not much altered, and they can be divided into five stratigraphical divisions, which are shown below with the highest at the top:—

		Approx. thickness in ft.
Applecross Group.	Red and chocolate Arkoses, with seams containing pebbles of quartzite, quartz-felsite, jasper etc.	5000, without reaching the top.
Diabaig Group.	Kinloch Beds. Dark grey sandy shales and grey and buff grits with thin calcareous seams and lenticles.	3600.
	Beinn na Seamraig Grits. Buff and grey grits with bands of grey sandy shale.	2600 (Loch Eishort).
	Loch na Dal Shale Series. Dark grey gritty or sandy shales with buff grits and thin calcareous seams and lenticles.	600 to 1200.
	Epidotic Grits and Conglomerates.	200 to 300, without reaching the base.

The three upper members of the Diabaig group have many characters in common, and they are coloured the same in the published map though the boundaries of each are generally engraved. The grits usually weather brown and are often false-bedded, and, as in the Applecross group also, the minor laminæ are often arranged in curves, frequently sharp, even in places where the surfaces of the beds composed of them are even. A few of the coarser grits are red owing to the abundance of clastic grains of red felspar, but in most cases the felspar grains are white, and many are composed of oligoclase. As in the Applecross grits, the felspars are often in a fresh condition, a fact which has given rise to the supposition that the Torridonian rocks have been formed under desert conditions.* The quartz grains are often opalescent and slightly blue. Many of the finer grits are marked by small pale spots which seem due to some condition of the interstitial matter. The shales are nearly always closely mixed with thin sandy laminæ.

The general strike is north-east and south-west, and, in making a traverse from the outskirts of Broadford in a south-east direction to the coast a little north-east of Ardnameacan, we see all five divisions in their simplest relations and dipping north-west, generally from 20° to 70°. The rocks in the greater part of the traverse are free from folds and thrusts and cleavage, but the south-eastern end, which is probably near the Moine thrust, shows sharp folds and some degree of dynamo-metamorphism. In all the northern half of the peninsula, the rocks which lie furthest south-east are more affected by dynamo-metamorphism than those to the north-west of them, but in proceeding towards the north-east, along the strike of any bed, the degree of metamorphism also increases, and in conformity with this latter rule the green grits near Ardnameacan are less altered—less deformed and less lustrous—than those near Port Aslaig.

The direction of dip is not generally so uniform as in the traverse mentioned. The description of the detailed structure is, however, reserved for Chap. VI.

DIABAIG GROUP.

The epidotic grits form four small areas on the coast between Kyle Rhea and Loch na Dal, the three most south-east being, however, very close together. Different beds vary considerably in coarseness of grain and colour, but many are either green from chlorite or lemon-yellow from small grains of epidote, some of which are enclosed in felspar grains, and have evidently been formed from felspar. In various parts of the North-West Highlands the pre-Torridon surfaces of the Lewisian gneiss are largely epidotised, and there is nothing surprising in finding clastic grains of epidote in beds which have been to a large extent formed by denudation from such surfaces. The larger grains and pebbles consist chiefly of quartz, often of an opalescent character, and red felspar, together with rarer specimens of composite rocks, including gneiss, quartzite and quartz-felsite. The pebbles are usually larger than those in the other Torridonian divisions, but less than a pigeon's egg. Bands of purple or green sandy

* J. G. Goodchild, "Desert Conditions in Britain," *Trans. Edin. Geol. Soc.*, 1896, vol. vii. p. 220.

shale are occasionally interbedded with the grits, and near the top some of a grey colour also occur.

The outcrop of the Loch na Dal series extends from the eastern side of Kyle Rhea, where it is in places no more than 15 yds. broad, to a little distance south-west of Loch na Dal, where it becomes covered by Moine schists, but it is interrupted by the sea in two places, Kyle Rhea and Loch na Dal.

The shales frequently show sedimentary flakes of white mica and ripple-marks : in the intermixed gritty laminæ the clastic grains are sometimes as large as peas, and grains of the same size are occasionally found isolated in shale. Near Port Aslaig there is a band of shale, perhaps 18 ft. thick, which is less sandy than the others and slightly calcareous in places. A thin dark grey impure limestone on the shore about a third of a mile north-east of Ardnameacan is perhaps on the same horizon. The other calcareous streaks and lenticles, though extremely abundant, contain a considerable amount of sandy matter, and are never more than six inches thick.

The Beinn na Seamraig grits are found on both sides of Kyle Rhea, and extend thence over Ben Aslak, Beinn na Seamraig and A' Mhaoile—a mile or two south-west of which they become covered by rocks carried forward on the Moine thrust. About a mile W.S.W. of Port Aslaig the base line is folded along axes striking north-east, and near Beinn Bhuidhe and Allt Eas a' Mhuic the top is obscure and has not been engraved on the map. Some reddish grits which emerge from below the Moine thrust near the southern margin of the map probably also belong to this series.

Thin impure calcareous seams and lenticles sometimes occur, but rarely. The intermixed shale bands increase in number near the top, which is not sharply defined. Specimen 7679, which was collected from a locality near Bernera, from a grit which is considerably sheared but of a common type, has been analysed by Dr. Teall, with the following result :—

SiO_2	73·56
Al_2O_3	13·62
Fe_2O_3	2·3
CaO	1·04
MgO	trace
K_2O	4·24
Na_2O	3·98
Loss on ignition	1·08
	99·82

The Kinloch beds occupy more area than any other Diabaig division. They extend from Loch Alsh nearly to the southern margin of the map, where they bend to the north, but near Tokavaig they twist again into a south-west strike. They compose most of the small islands in Tarskavaig Bay and a narrow interrupted strip extending a mile south-west of it. A fault striking north-west, with a large downthrow to the north-east, crosses the outcrop near Loch an Iasgaich, and on the south-west side of this fault an important thrust plane emerges, which has been folded into an anti-

cline : the top of the anticline has been denuded away, and the rocks below the thrust, which include some small patches of the Kinloch beds, are exposed. A small detached area, appearing from beneath the Moine thrust, is also seen in Allt a' Mhuilinn.

Shales are in most parts somewhat subordinate to grits. The sandy laminæ in the shales are, perhaps, rather less coarse than in the Loch na Dal series, and calcareous bands are somewhat less numerous. On the other hand, thick massive grits are more abundant. Some of the grits contain layers of magnetite and other heavy minerals, which no doubt represent magnetic sands locally concentrated by current action. One layer, about 100 yds. slightly north of east of the Ordnance Station on Sgurr na Coinnich, is an inch or more thick, but not traceable more than a few yards. It is polar magnetic, and Mr. Allan Dick reports that it contains 27·5 per cent. of metallic iron, equivalent to 37·97 per cent. of magnetite. Another magnetic layer on An Sgulan is sometimes six inches thick.

Ripple-marks are well seen in the grits and shales on the coast south-west of Òb Gauscavaig, and rain-pitted surfaces have been observed in some shales in the burn north-east of Kinloch.

The line between this and the Applecross division is not well defined, a passage zone coming between the two, which contains strata of types characteristic of both.

Three-quarters of a mile north-east of Tarskavaig, the Kinloch beds near a small outlier of Mesozoic calcareous conglomerate are stained red and traversed by many limestone streaks.

APPLECROSS GROUP.

The beds of this group, consisting chiefly of grits or arkoses, form a broad band, extending from Lusa and Kyle Akin to Loch Eishort, the north-west side of which is in most places covered unconformably by Mesozoic rocks. They also form most of the complicated area exposed beneath the folded thrust-plane on the south-east side of the large fault which passes near Loch an Iasgaich, as well as a detached band, in a reversed position, on the west side of the west limb of this thrust. The small Torridonian tract on the flanks of Ben Suardal is entirely composed of Applecross grits, separated from the Cambrian limestone below by a thrust-plane which has been folded into an anticline.

In the common red or purple arkoses or grits, the larger clastic grains, which seem to consist mainly of red potash felspar and opalescent quartz, do not exceed the size of a mustard seed, being much smaller than those in the grits in Applecross and the districts further north. The grains and pebbles of composite rocks, including pink and purple quartzite, quartz-felsite and jasper, are larger than the other grains, but rarely exceed an inch in length.

False-bedding is very prevalent. We repeatedly find laminæ which have been sharply folded before the deposition of the beds just above them.* Thin calcareous lenticles are occasionally observed, but are never more than a few inches thick. Laminæ, rarely more than an eighth of an inch thick, which are almost black

* Similar phenomena occur in unaltered Carboniferous rocks. Perhaps they are due to slipping along a steep floor.

with grains of iron ore, are sometimes found in the redder rocks, and the grains in a specimen from the coast near Ob Allt an Daraich have been found to consist of magnetite.

Bands of sandy shale, of Indian red, purple or greenish tints, and rarely more than a few feet thick, are occasionally seen in the middle and upper portions of the group.

Near the base of the Mesozoic rocks the Applecross grits have been stained by percolation from above, and show evidence also of having been deeply weathered and jointed prior to the deposition of these rocks. Near the bridge over Abhuinn Ashik and nearly a third of a mile north-east of the outlet of Loch Buidhe, they are crossed by so many irregular calcareous streaks and veins of limestone, the substance of which has no doubt been derived from the overlying limestones, that the line of junction between the Applecross and the Mesozoic rocks is a little uncertain.

At the sides of intrusive dykes the Applecross rocks are usually changed into a dirty white or buff colour, and assume a conchoidal fracture. In certain places near Broadford they are altered in an unusual degree, and contain short strings and spots of epidote, as is seen in Allt a' Mhuilinn, two-thirds of a mile E.S.E. of Broadford Parish Church. C. T. C.

Section II.—Mainland North of Loch Alsh.

INTRODUCTION.

In this district all the strata of Torridon Sandstone age are inverted, with the exception of those occupying a strip of ground about half a mile broad extending along the shore from Kyle Akin northwards to Plockton. The Diabaig and Applecross groups are both represented, but the overlying Aultbea series, forming the highest division in Ross-shire (Sheet 91), has not been detected.

DIABAIG GROUP.

Adopting the classification established in Skye, we find this group in the present district to consist of the following subdivisions in descending order :—

(*d*) Grey sandy shales and fine-grained sandstones with massive grey and green grits; thickness 2700 ft. (Kinloch Beds).
(*c*) Fine-grained grey and green grits, sandstones, and flags; thickness 1200 ft. (Beinn na Seamraig Grits).
(*b*) Grey, blue, and black shales, with calcareous bands and grits sometimes calcareous; thickness 500 ft. (Loch na Dal Beds).
(*a*) Green epidotic grits with a conglomerate at the base, locally developed; thickness 60 ft.

The conglomerate at the base of the epidotic grits is best seen at Fernaig, by the roadside leading from Stromeferry to Plockton, where it dips in inverted order beneath the Lewisian gneiss. The matrix contains pebbles of various types of epidotic gneiss and of vein quartz usually stained purple, and shows marked cataclastic structures. The epidotic grits, which are charged with epidote and chlorite, show on the weathered surface numerous grains of blue

quartz and epidotised felspar. Under the microscope the larger grains, specially of quartz, are granulitised, and the matrix often forms a granulitic mosaic, rich in epidote and chlorite. This band of green epidotic grits can be traced continuously round the crag from Fernaig to the valley of Gleannan Dorch, where they are truncated by a thrust to be referred to in the sequel.

The Loch na Dal subdivision consists of grey, blue, and dark striped shales, flags, and calcareous bands, alternating with green and grey banded sandstones and pebbly grits. Some of the bands of shale and grit effervesce freely with acid, the grit frequently weathering with a carious surface. Further, the grits show marked flaser structure; the finer grains have been granulitised, while those of larger size show peripheral granulitisation. Sericite and in some instances brown mica have been developed as a result of the dynamic metamorphism which these rocks have undergone. At Fernaig, they appear on the roadside and can be traced round the face of the great crag east of Duncraig to Gleannan Dorch.

The Beinn na Seamraig subdivision is composed of grey and green grits, showing alternations of fine flaggy sandstones with derivative mica, and containing lines of heavy minerals (iron ores and sphene). Green sandy phyllites sometimes occur among them. The grits contain quartz, microcline, and oligoclase embedded in a matrix usually granulitic, and containing sericitic mica. These strata are frequently traversed by quartzo-felspathic veins and strings of quartz, and vermicular chlorite. This subdivision occupies a strip about three-quarters of a mile broad to the west of the striped Loch na Dal shales, from the northern margin of the map south as far as Gleannan Dorch.

The prominent feature of the Kinloch beds is the occurrence of zones of grey sandy shale, which at some places have been quarried for slates. These shales are associated with sandstones, flags, and massive grits, which, with their included quartz and felspar fragments, resemble arkoses of the Applecross group. In places along their outcrop the grits are markedly schistose, as, for instance, near Duncraig, where they contain clastic grains of quartz, microcline, and oligoclase, lying in a micro-crystalline matrix of sericite and chlorite, showing flaser structure. The shales of this group are specially developed on two horizons—one near the top and the other near the base. The higher belt, which, as the strata are here inverted, is the more westerly of the two, is well exposed on the shore about half a mile east of the Kyle of Loch Alsh. They are traceable northwards by Loch Scalpaidh to Allt Dhuirinish, where they are worked for roofing slate, to the shore of Loch Carron between Duncraig and Plockton. The pebbly grits and sandstones lying between the upper and lower shale-zones are well seen on the north shore of Loch Alsh between the Bay of Scalpaidh and Balmacara. They also form the wooded hills south of Duncraig.

APPLECROSS GROUP.

The sandstones and grits so characteristic of this group are here finer-grained than in the typical Loch Torridon area. In places they are pebbly and contain fragments of microcline and pink felsite.

Lines and thin bands of heavy minerals—magnetite and zircon—are intercalated in some of the beds of arkose, as, for instance, in the Plock of Kyle, a quarter of a mile west of Kyle Inn. In some cases the bands containing these heavy minerals vary from two to ten inches in thickness. The arkoses form a belt upwards of a mile in width along the western seaboard from Kyle Inn north by Duirinish to Plockton. Over the greater part of this area their dip is easterly and inverted.

To the east of the area of Torridon sandstone here described, between Loch Carron and Loch Alsh, minor infolds of this formation have been caught in among the masses of deformed Lewisian gneiss. The strata so included comprise the basal conglomerate, the epidotic grits, the Loch na Dal shales, and some of the Beinn na Seamraig grits, all showing perhaps more advanced traces of deformation than those above noticed as observable between Fernaig and the Kyle of Loch Alsh. B. N. P., J. H.

Section III.—Scalpa and the Adjacent Portion of Skye.

Sandstones of Torridonian age make up the greater part of Scalpa, besides the adjacent Longay and smaller islets and rocks, but the different groups have not been correlated with the divisions established in the south-eastern peninsula of Skye or on the mainland. There is a general dip of about 20° to N.W., modified, however, especially in the southern portion of Scalpa, by disturbances of a more complex nature. The visible succession may be divided into two groups, which have been separated on the map, viz. :—

Upper : coarse sandstones, often pebbly, 4750 ft. ; no summit.
Lower : fine sandstones, often flaggy, 1300 ft. ; no base seen.

The upper and principal group, occupying roughly the north-eastern half of the island, consists of coarse reddish felspathic sandstones, often current-bedded ; many of the beds containing small rolled pebbles up to an inch in diameter, or exceptionally two or three inches. The rocks are well bedded, and the monotonous succession of small escarpments gives a very characteristic type of scenery. The estimated thickness is taken on the assumption that this represents an unbroken normal sequence. The lower division consists of beds of finer texture. At the top are felspathic sandstones, often with a reddish tint on weathered faces ; having, moreover, a laminated aspect and a flaggy fracture. These pass downward into close-grained quartzose grits, with little felspathic material, which are the lowest beds seen.

On the Skye side of the Sound of Scalpa the Torridonian rocks are seen in detached areas of no great size, much involved with the Tertiary intrusions of gabbro and granite, and the variable dips observed are connected with local disturbances. The strata represented appear to correspond with the lower part of the Scalpa succession. They are mostly medium to fine-grained sandstones ; in places felspathic, but often purely quartzose. They pass sometimes into quartzites, as may be seen at the Allt Fearna bridge, at two or three spots on the southerly slope of Creag Strollamus, and in the small outliers above the overthrust about a mile west of Broadford.

Torridonian rocks reappear to the north of the granite area, between Loch Ainort and Loch Sligachan. A strip two and a quarter miles long extends from Maol na Gainmhich to near Sconser Lodge, where it is overlain by the Trias conglomerate. It shows dips in varying directions at moderately low angles. The prevalent lithological type is a rather close-grained grey or pink felspathic grit; but west of Tormichaig the rocks are of coarser texture, with some pebbly beds. The Torridon Sandstone is brought up again in the much faulted ground forming the slope above the Sconser crofts; and its last appearance is in a small area on the west slope of Glamaig, cut off to the west by a fault bringing down the basalt lavas. A. H.

Section IV.—Raasay.

Betweeen Rudha na Cloiche and Eyre Point cliffs and inland scarps of New Red Sandstone and conglomerate overlie Torridon Sandstone. In places these two formations, that are separated by an enormous interval of time, appear in apparent conformity, and it is not surprising that the older observers made no distinction between them. Elsewhere, however, the discordance is obvious.

The Torridon Sandstone which in one locality seems to be well bedded is seen not far away to be violently and irregularly contorted.* It consists of hard red and purplish sandstone with seams of quartz conglomerate, and it is more sharply jointed than the overlying New Red rocks. In general aspect it resembles Old Red Sandstone, with which indeed it was grouped by Hugh Miller. Some varieties of the rock when freshly broken present a granitic appearance, and are indeed an arkose composed of fragments of quartz, felspar and mica. H. B. W.

Section V.—The Crowlin Isles.

The southern portion of these isles, situated about four miles to the north-east of Scalpa, is included in sheet 71. They are formed of a series of hard sandstones and shales, belonging to the uppermost or Aultbea group of the Torridon formation, which lie to the west of the great post-Cambrian lines of displacement. The sandstones are reddish and grey in colour, fine-grained, compact and hard in texture. In composition they are fine-grained arkoses, in which the felspar grains are remarkably fresh. They are divided into massive beds, from two or three feet even up to twenty feet in thickness, which may succeed each other without any parting of other material. A thin layer, however, of green, red, or grey micaceous flagstone or shale not infrequently intervenes between them. Such layers of shale occasionally reach a thickness of from fourteen to twenty feet, and they here and there show evidence of having been locally eroded before the deposition of the overlying sandstone. It is not uncommon, therefore, to find more or less rounded galls of shale in the sandstones. As the dip of the strata through the islands is towards the N.N.W. at an average angle of about 15° the thickness of the strata here exposed must amount to above 2000 ft.

B. N. P.

* This is not in consequence of post-Cambrian movements. See description of Applecross group in Section I. C. T. C.

Section VI. Strathaird.

Low-lying Torridonian rocks extend northward from Camasunary into the south end of Blath-bheinn or Blaven.* Massive grey and pink felspathic sandstone and coarser grit with pebbly seams predominate in the central and eastern parts, dark shales being confined to occasional thin bands on the east. But on the west, where the dip is uniformly north-west, black shale with some whitish laminæ assumes greater proportions. West of the bay dark shale with thin flags passes up into light grey sandstone.

These rocks appear to be different from those in Soay † and the adjacent coast of Skye, and in view of the north-westerly dip it seems probable that they are somewhat older. They may, therefore, belong to the Diabaig group. C. B. W.

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 131.

† See C. T. Clough, "The Geology of West-Central Skye, with Soay," *Mem. Geol. Survey*, 1904, p. 4.

CHAPTER V.

CAMBRIAN FORMATION.

Introduction.

All the Cambrian rocks have probably been thrust from the south-east by the great post-Cambrian movements, and nearly all have been formerly covered by Torridonian rocks carried forward by thrusts: the thrusts have been folded into anticlines, and in the course of denudation some of the rocks below have been exposed.*

The divisions represented are shown in the following list, with the youngest at the top :—

		Estimated thickness in ft.
Durness Dolomite and Limestone.	Ben Suardal zone. Probably homotaxial with the Balnakiel and Croisphuil zone of Sutherland	..
	Strath Suardal and Beinn an Dubhaich zone (?)	..
	Sangomhor zone	..
	Sailmohr	270
	Eileandubh	500
	Ghrudaidh	115
	Serpulite Grit..	50
	"Fucoid-Shales," with lenticular bands of ferruginous limestone	60
Quartzite.	Upper Division or "Pipe-Rock," in six zones, characterised by different varieties of "pipes" (vertical worm tubes)	270
	Lower or False-bedded division	330

In the above list the Strath Suardal and Beinn an Dubhaich beds are placed together. They differ considerably in appearance, but it seems possible that they represent different phases of alteration of one horizon.

A controversy was waged for many years respecting the age of the limestones in the Broadford district, and it was not until 1888 that Sir A. Geikie † finally proved their Palaeozoic age.

Broadford and Ord Areas.

QUARTZITE.

This rock composes Sgiath-bheinn an Uird, Sgiath-bheinn Chrossavaig, Sgiath-bheinn-Tokavaig and other hills near Ord which

* The details of parts of the structure are described in Chapter VI.

† "On the Age of the Altered Limestone of Strath, Skye," *Quart. Journ. Geol. Soc.*, vol. xliv. p. 62.

gleam in the distance almost like snow. The band forming Sgiathbheinn Tokavaig extends into a chain of islands in Loch Eishort, and some small exposures on the north side of it, which are covered by Mesozoic rocks.

At the base of the lower division a thin pebbly bed or conglomerate, containing small pebbles chiefly of quartz, is found, but is never more than five or six feet thick, and sometimes only a few inches.

Dr. Peach states * that the upper division or "pipe-rock" has yielded all the kinds of "pipes" that characterise the corresponding division on the mainland, viz. :—

Scolithus linearis :

sp. No. 1 (small pipes).
sp. No. 2 (common pipes).
sp. No. 3 (trumpet pipes) = *Arenicolites* of Salter.
sp. No. 4 (Serpulite Grit pipes).

The six members of the upper division are described in the following list :—

	Estimated thickness in ft.
6. Top rock. White or reddish grey. Often rather coarse-grained and friable. Occasional "pipes" with tops three inches wide	20
5. Alternating massive and thinner beds. Matrix of Indian red colour, but "pipes" white	20–30
4. "Trumpet pipe-rock." False-bedded, white or brownish. Unusually massive near the top. Tops of "pipes" vary greatly in diameter, some being three inches and others only an eighth of an inch : in the "trumpet pipes" the tops are oval and large and the diameter of the "pipe" decreases rapidly downwards	55
3. Massive pink "pipe-rock." In the bottom ten feet the tops of many of the "pipes" are only a sixteenth of an inch across ..	55
2. Massive white "pipe-rock." "Pipes" usually about a quarter of an inch across	35
1. "Small pipe-rock," white and somewhat massive. "Pipes" usually only an eighth of an inch across, and scarce in some false-bedded rippled beds	55–60

In Ord River, south-east of Teampuill Chaon, the bed at the top of the quartzite is a soft reddish brown grit with dark green specks resembling glauconite. Microscopic examination of a thin slice (7356) shows that each original clastic quartz grain has been enlarged by a growth of secondary quartz in optical continuity with it, and that the surfaces of many of the grains had previously been coated with ferric oxide.

The floor on which the quartzite was deposited consists exclusively of Torridon rocks of the Applecross division, and must have formed a very even surface. The difference in dip and strike between the quartzite and these rocks is hardly recognisable in small areas, but putting all the evidence together it seems clear that the latter must have had a gentle north-easterly dip at the time the quartzite was being deposited.

There is no cleavage in any beds, nor any noticeable drag of the "pipes" out of the vertical position, but near some of the thrusts the bedding is hidden by joints and lines of movements.

* *Summary of Progress* for 1898, p. 54.

"FUCOID SHALES."

These beds often form smooth grassy ground and hollows between the quartzite and serpulite grit. They are seen on the west sides of the three bands of quartzite which form Sgiath-bheinn an Uird, Sgiath-bheinn Chrossavaig and Sgiath-bheinn Tokavaig, as well as in some small exposures in and a little distance south of Ord Bay.

About a quarter of a mile S.S.W. of Rudha Dubh Ard the bottom 30 ft. consist of brown weathering sandy shales mixed with thin yellow calcareous flags, and above these come greenish-grey or bluish-purple shales mixed with thin brown sandy bands. In some places the lower beds include one or two lenticular bands of ferruginous limestone or dolomite, one of which is sometimes as much as 6 ft. thick.

Mr. Macconochie has found the *Olenellus* fauna in beds near Ord and in the burn about three-quarters of a mile south of the mouth of Ord River. Below is a list of the fossils, which have been identified by Dr. Peach :—

Planolites sp.	Trilobite (not Olenellus).
Olenellus reticulatus *Peach.*	Hyolithes sp.
Olenelloides armata *Peach.*	Salterella pulchella *Bill.*

The flattened worm-casts, which were formerly supposed to represent fucoidal impressions, are well seen by the road 250 yds. S.S.E. of the bridge at the mouth of the Ord River, and on the hill a little more than half a mile south-east of Sgeir Gormul.

None of the beds are cleaved.

SERPULITE GRIT.

The longest outcrop comes conformably over the fucoid shales on the west sides of Sgiath-bheinn Tokavaig and Cnoc an Uairidh. Another long band extends from the coast 1000 yds. E.S.E. of Sgeir Gormul for a considerable distance inland, and a little further west there are other patches, due to repetition by small thrusts. In and a little south of Ord Bay the bed is also seen, and in an exposure near the centre of the bay the remains of *Serpulites* are distinct. About 700 yds. slightly west of south of Rudha Dubh Ard the grit shows marks which resemble the mouths of large "pipes."

The bed is of a somewhat variable character, some parts being extremely hard and white, while others, irregularly mixed with the harder but especially common near the top, are of loose texture, brown and carious.

DURNESS DOLOMITE AND LIMESTONE.

Excepting when thermo-metamorphosed, all the zones save that of Ben Suardal appear to be dolomitic to a considerable extent, their specific gravities usually ranging between 2·80 and 2·85.

It is only in the Ord area that the three lowest zones are found, together with a small exposure belonging to the Sangomore zone of Sutherland. In the Broadford district only the higher zones occur, and the beds are generally much more altered than those of Ord, both by dynamo-metamorphism and by granitic intrusions.

The Ghrudaidh beds are well seen on the hillside east of Ord and in the burn 1500 yds. slightly west of south of Ord. The bottom part, about 15 ft. thick, is of a granular texture, contains small grains of quartz, and weathers with a deep brown colour. Above this comes a granular leaden-coloured rock about 65 ft. thick, and above this again a series of alternating granular and more compact pale bands, some of the former containing oolitic structures which are occasionally preserved in chert. In other areas forms of *Salterella* which are found in the *Olenellus* zone of America are found in two bands slightly above the base of the Ghrudhaidh zone, and Dr. Peach, therefore, classes the lower part of this zone as Lower Cambrian.*

The Eileandubh beds occupy more area than any of the others found near Ord, and are exposed on the coast north and north-east of this place. Most of them are flaggy, compact and white or cream-coloured, but mixed with these are others of coarser texture and leaden colour. Lumps and bands of chert—grey, black or occasionally red, and sometimes as much as 2 or 3 ft. thick—occur in abundance in the lower and upper parts, but are rare in the middle portion. The top is not sharply defined.

The Sailmohr beds are granular, mostly of a leaden colour, and contain chert in great abundance. The best exposures are on the coast north-west of Ord and at the road near the shore S.S.W. of Ord.

Beds belonging to the Sangomohr zone are exposed on the west side of the Sailmohr beds in the wood 700 yds. S.S.W. of Ord. They are granular and white, and contain bands of white chert 2 or 3 ft. thick.

The Beinn an Dubhaich beds form a considerable area on the north-east side of the Beinn an Dubhaich granite, and are always in a highly metamorphosed condition, forming "the Strath Marble." They contain numbers of spheroidal or oval structures, often several inches across, composed of concentric rings which, in natural sections, project slightly from the intervening substance. These structures have perhaps only been made manifest by contact metamorphism, for in the Eileandubh limestone of Sutherland similar forms are abundant near the big intrusions, but are never found elsewhere.†

The Strath Suardal beds are found at further distances from the granite referred to than those just described, but they also are often considerably altered. Most of them are dark grey or almost black, granular in texture and full of chert lumps, often an inch or two in diameter, which resemble sponges in shape, but do not show any clear organic structure.

The Ben Suardal zone forms most of Ben Suardal and covers a larger area than any other. The top is not seen, and the exposures are complicated with isoclinal folds and thrusts, but for the most part not much altered by contact metamorphism. Excepting where thus altered the texture is somewhat fine, and the fresh fracture dark, though the weathered crust is pale grey. Small lumps and courses of black chert, often from half an inch to an inch thick, are very abundant, and mixed with nearly horizontal worm-casts crossing one another in all directions, and often weathering with a pale grey or buff colour. In one locality, about 700 yds. slightly north of west of

* "Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, p. 375.

† Information given by Dr. Peach and Dr. Horne.

Loch Lonachan outlet, a band contains oolitic structures as large as peas.

Certain beds, some of which certainly occur near the base, contain a good number of fossils, and from the collections made by Mr. Macconochie and others, in the different localities, including those in the districts to be described in the next section, Dr. Peach has made out a fossil list which is given in the Appendix.*

Dr. Peach states,† "A glance at the list is sufficient to show that the limestones from which the fossils were obtained represent the Balnakiel and Croisphuil groups of Durness. Several of the species here indicated are found also in Newfoundland. . . . Accepting, as there seems good reason to do, the classification of the Newfoundland rocks, the fossils here tabulated appear to be of Middle or Upper Cambrian Age."

The top of a prominent limestone knoll, on the east side of the road about a mile and a half south of Broadford Hotel, is particularly rich in fossils, and has provided all the species shown in the following list, as well as some others :—

Archæoscyphia minganensis (*Bill.*).
Euchasma blumenbachi *Bill.*
Chelodes sp.
Maclurea acuminata *Bill.*
„ crenulata *Bill.*
„ emmonsi *Bill.*
„ peachi *Salt.*
Lophospira augustina (*Bill.*).
„ borealis *Donald.*
Ectomaria pagoda (*Salt.*), *var.* orientalis *Donald.*
"Pleurotomaria" calcifera *Bill.*
„ turgida *Hall.*
Raphistomina laurentina (*Bill.*).
Euconia ramsayi (*Bill.*).
Endoceras sp.
Orthoceras durinum *Blake.*
„ pertinens *Blake.*
Piloceras invaginatum *Salt.*
Trocholites sp.

On the north-west shore of Loch Lonachan the chert lumps have been dragged out in the course of the great post-Cambrian movements into trains of small granules at right angles to the strike, and some specimens of *Maclurea* have been elongated in the same direction.

C. T. C.

Kilchrist and Torran Areas.

QUARTZITE.

A small patch of quartzite, 500 yds. long, is exposed about three quarters of a mile south-east of the summit of Beinn an Dubhaich. It has a dip of about 45° to S.W., nearly agreeing with that of the Torridon Sandstone which emerges from below to the east. On the north side it is faulted against the limestone, and to the south it is covered by the Triassic conglomerate. The quartzite is of white colour and compact grain, but locally it contains small quartz pebbles up to an eighth of an inch in diameter.

A very small outlier of conglomeratic quartzite rests on a little overthrust patch of Torridonian in Allt Beinn Deirge, just above the principal sharp bend of the stream. Beyond this the rock has not

* Sir A. Geikie published (*op. cit.*) a list of fossils which were determined by Mr. George Sharman.

† *Summary of Progress* for 1898, p. 55.

been seen except at one place on the coast near the mouth of Allt Fearna, where it is wedged in a fault in that much broken strip of country.

DURNESS DOLOMITE AND LIMESTONE.

The anticlinal axis of Ben Suardal is prolonged W.S.W and W. through Beinn an Dubhaich, the granite which forms the core of that hill having the Cambrian limestones dipping away on both sides of it. In the neighbourhood of the granite the rocks are greatly metamorphosed, giving rise to a variety of silicate-bearing marbles. The lowest strata, seen in contact with the intrusive rock in the eastern part of the hill, belong to the Beinn an Dubhaich and Strath Suardal zone, and are here characterised by the occurrence of remarkable concentric-shell structures often a foot or more in diameter,* showing on a fractured surface a large number of concentric rings, more and less siliceous alternating. These structures are formed round sponges, which are usually quite obliterated in this part. On the southern side of the anticline, in the upper (outer) part of the zone, the sponge-forms are well seen. Beyond this again, and in the corresponding position on the north side, towards the high road and Loch Kilchrist, comes the Ben Suardal zone, with abundant small black cherts and often full of worm-casts. Westward this upper zone comes into contact with the granite, and is metamorphosed. In its non-metamorphosed state it is a pale close-grained rock with marked lamination and bedding. It is well seen along the high road and about Torran, where it makes a considerable spread. This zone is not often dolomitised: the lower Beinn an Dubhaich and Strath Suardal zone, on the other hand, is usually so, though it becomes de-dolomitised by metamorphism.

The sponge-bearing Strath Suardal limestone is best seen on the floor of the strath, along and to the west of the Broadford River. There it is a dark saccharoid dolomite enclosing sponge-formed cherts of paler colour, often arranged in bands. The dolomitisation has obliterated the lamination, which is seen only in some patches which have escaped this change. To the west of this area is one of the Beinn an Dubhaich limestone, with the concentric rings already mentioned.

Entangled in the gabbro and granite to the north-west of Broadford are many small patches of Cambrian limestone in a metamorphosed condition. Those in the gabbro all belong to the Beinn an Dubhaich horizon, with concentric rings; but farther west, in the granite, patches of the sponge-bearing division occur, and also of the Ben Suardal limestone with its small black cherts. This last is seen again on the south-east slope of Creag Strollamus, being the last exposures of Cambrian strata in this direction. A. H.

* Described by Messrs. King and Rowney in their paper "On the so-called Eozoonal Rock," *Quart. Journ. Geol. Soc.*, 1866, vol. xxii. p. 185.

CHAPTER VI.

THE POST-CAMBRIAN THRUSTS AND FOLDS.

Area North of Loch Alsh.

The most striking feature of the belt of complication north of Loch Alsh is the great inversion of the Torridon Sandstone and Lewisian rocks above the Kishorn thrust-plane. The overturned gneissic floor, lying at a gentle angle on the inverted epidotic grits, black shales, and sandstones of the lowest Torridon division forms a conspicuous escarpment to the east of Duncraig. The boundary line between the two formations has been traced from Fernaig southwards to Gleannan Dorch, where it is truncated by the Balmacara thrust. Beyond that point to the shore of Loch Alsh this plane of movement separates the two rock groups.

A high grade of metamorphism is observable among the lowest Torridon strata, at or near their inverted base line and also in the overlying Lewisian rocks. New divisional planes have arisen which are inclined at gentle angles to the E.S.E. Above the Balmacara thrust-plane that stretches from the shore of Loch Alsh at Ard Hill north to near the head of Balmacara Burn, and thence in a winding course round Coille Mhor and Sgorr Beag to Gleannan Dorch, highly deformed Lewisian gneiss occurs, together with patches of epidotic grits and shales, which have also undergone alteration.

The position of the Moine thrust-plane is defined at certain places between Braeintra in Srath Ascaig and Kirkton of Lochalsh. Of special interest is the evidence of the crushing and deformation of the siliceous schists above that plane. One of the best sections illustrating the breaking down of the structures of the Moine schists is to be found in the small burn that crosses the road a little to the north of the bridge at Braeintra. Here the stream flows over the striped Lewisian gneiss while the walls of the gorge are composed of siliceous schists. The plane of the Moine thrust is laid bare not far upstream, and the flaggy siliceous schists are seen to be much puckered and deformed as they approach the line of disruption. Similar evidence is obtained in the burn that runs parallel with the high road about half a mile south of Braeintra, and also near the head of Auchtertyre Burn about a mile to the north of Auchtertyre farmhouse at Kirkton of Lochalsh.

At a point about half-way between Srath Ascaig and Kirkton of Lochalsh, the Moine thrust-plane with the overlying siliceous schists and the underlying striped Lewisian gneiss are thrown into a sharp overfold which pitches at a high angle to the south. The effect of denudation has been to cause the outcrop of the plane and the overlying schists to assume the form of a loop as laid down in the map.

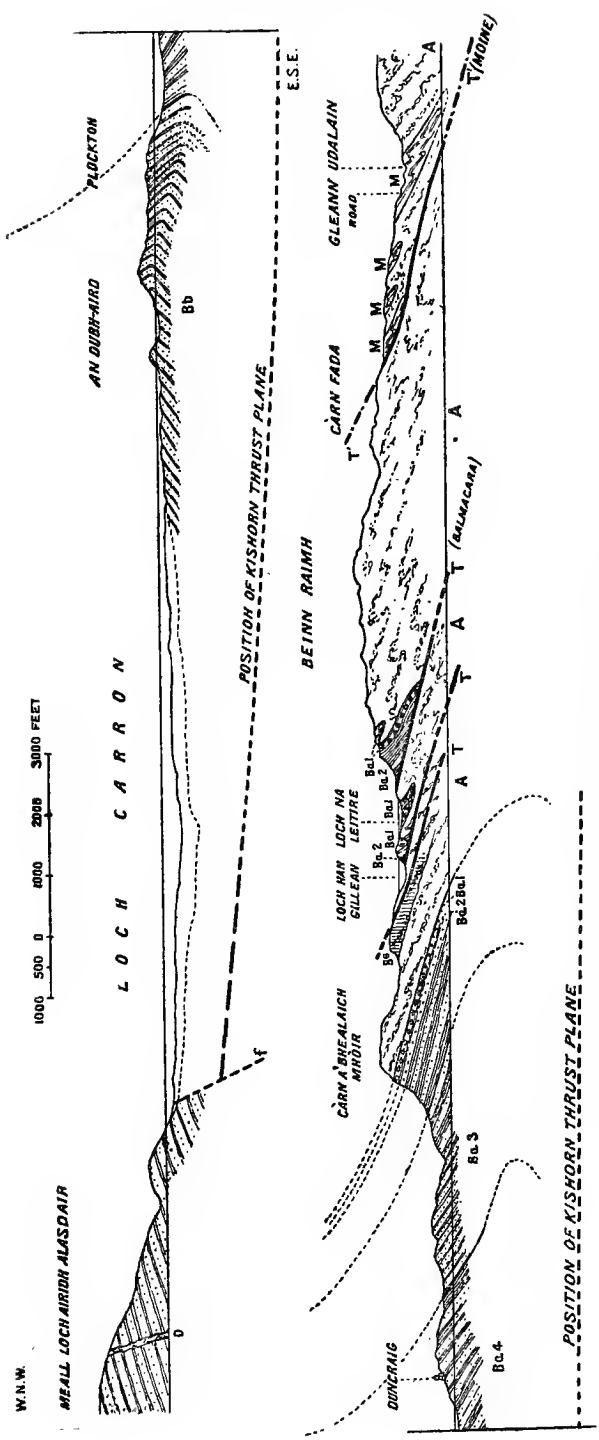


Fig. 7.—Section from Loch Carron by Plockton and Beinn Raimh to Gleann Udalain.

A, Lewisian Gneiss. B^{c}. Epidiorite and Hornblende-Schist in Gneiss. Ba^{1} to Ba^{4}. Diabaig Group (Torridonian). Bb. Applecross Group.
M. Moine Schists. D. Tertiary Dyke. T. Thrusts. T'. Moine Thrust. f. Fault.

The complicated geological structure of the northern portion of this area is best illustrated by the section (Fig. 7) drawn from Loch Carron eastwards to Gleann Udalain.

East of the headland of An Dubh Aird, at the mouth of Loch Carron, all the Torridon strata are inverted (Fig. 7). The axial line along which the inversion begins is situated among the members of the Applecross group (Bb), some of which have a normal dip to the west, while others are inclined to the east. As those with an eastward inclination are followed inland, they are seen to pass in inverted order beneath the Diabaig group (Ba). The zone of Kinloch beds (Ba^4) is developed round the shores of the bay between Plockton and Duncraig, whence it extends eastwards beyond the mansion of Duncraig. These are followed in inverted order by the other subdivisions of this lowest Torridonian group (Ba^3 to Ba^1), till, on the bold escarpment of Carn a' Bhealaich Mhòir, the basal conglomerate (Ba^1) is overlain by grey granulitic gneiss (A), on which it normally rests. Beyond the gneiss lies the hill of hornblende-schist (B^G), which is cut off by a thrust that brings forward platy crushed gneiss. Not far to the east a second thrust supervenes, which has driven westwards a slice of Lewisian gneiss, with small outliers of the basal members of the Torridon Sandstone (Ba^1, Ba^2), showing a high degree of metamorphism. The general strike of the foliation of the Lewisian series here is north-west and north-east, but near the lines of disruption it roughly coincides with their trend. The gneiss is massive and hornblendic with bands of epidiorite. The patches of inverted Torridon strata lie in several folds, two of which appear in the line of section (Fig. 7). They comprise the basal conglomerate, epidotic grits, together with dark shales and flaggy grey siliceous sandstones of the Loch na Dal group of Sleat. These rocks are visible on the south-east shore of Loch nan Gillean, and on the south side of Loch na Leitire, three miles north of Kirkton of Lochalsh, where they show flaser structure, peripheral granulitisation of the grains, and a development of sericitic mica.

About 100 yds. south of Loch na Leitire, the outcrop of an important thrust-plane (Balmacara) has been laid open in a small burn, where the grey flaggy beds of the Loch na Dal group are superimposed on sheared gneiss. On the cliff south of that lake the black shales of the Loch na Dal group are surmounted by the epidotic grits and basement conglomerate that pass, in inverted order, beneath the overturned Lewisian floor (A). Here the thrust Torridonian strata show a considerable degree of alteration. Still further to the east, along the same line of section, a remarkable development of intensely sheared gneiss appears on Beinn Raimh. In this Lewisian mass the original structures have been almost wholly effaced, its bands of acid and basic rock with pegmatites being now represented by red, grey and green striped mylonites. On the eastern declivity of the same hill these rocks are truncated by the Moine thrust (T'), which has here carried westwards four inverted folds of siliceous schist (M, M), with intervening bands of gneiss (A). The type of Lewisian rock in these intervening arches is a granulitic, epidotic, hornblende-biotite gneiss, with large lenticles of hornblende-schist. At the eastern margin of the third infold of siliceous schist, and at the western edge of the fourth belt, exposed in Gleann Udalain, a

conglomeratic rock makes its appearance, having a holo-crystalline, micaceous and hornblendic matrix, and containing pebbles of quartz and of an epidotic gneiss like the underlying Lewisian type.*

B. N. P., J. H.

Broadford and Ord, and the Areas to the East and South.

The outcrop of the Moine thrust—the most important structural line on the map—which has brought forward from the south-east the schists and gneisses in the south-eastern part of the sheet, is hidden under the sea for a considerable distance, and on the east side of Kyle Rhea it is also cut out by a fault with downthrow to the east. Its position is distinct, however, at Camas a Mhuilt, near Isle Ornsay, and it can be traced therefrom, without much difficulty, all the way to the southern margin of the map, where its general inclination to the E.S.E. is about 10°.†

The Tarskavaig thrust which carried forward the Tarskavaig Moine schists, and which has been folded into a syncline, with the east limb sometimes reversed, on the north-west side of the Moine thrust near the margin referred to, can be proved in the adjoining one-inch map 61 to occupy a position lower than the Moine thrust, but above the thrusts near Ord, which will shortly be depicted in horizontal sections.

In this district the thrusts differ from those further north-west in being more frequently in a folded condition, as already noticed, and also more often accompanied by crush breccias. Examples of the latter are found with the Sgiath-bheinn an Uird and the Sgiath-bheinn Tokavaig thrusts, as will be described subsequently, and there are also others in a somewhat more sheared condition. One, along the Tarskavaig thrust, is seen in the north-west bank of Gillean Burn, nearly three-quarters of a mile west of Loch Dhùgaill, and another, along the Moine thrust, in a burn rather more than half a mile south of Loch nan Uamh, where it is accompanied with a basaltic sheet which is not crushed.

We shall now illustrate the structure of different localities by horizontal sections, with brief descriptions, taking them in order from north-east to south-west.‡

Excepting a small patch on Dun Ruaige and an intrusive dyke (D, crossed twice by the line of section), the rocks in the Skye portion of Fig. 8 all belong to the Torridon formation. Most of these are not much altered, but it is clear from facts observed further south (see sections subsequently described) that they have all been thrust forward from the south-east over other rocks, consisting in part of Cambrian quartzite and limestone. They have been carried forward

* The geological structure of the belt immediately to the north of Loch Alsh, extending from Erbusaig by Balmacara and Kirkton Hill to Gleann Udalain, is described in the Memoir on "The Geological Structure of the North-West Highlands of Scotland," pp. 571–573.

† The relations between the Moine thrust and the folding of the overlying Moine rocks are referred to in Chapter III.

‡ All these sections are described in greater detail in the Memoir "On the Geological Structure of the North-West Highlands of Scotland," chap. xxxix.

en masse with comparatively little disturbance excepting near the axial plane, inclining gently south-east, of a great fold indicated in the section. Most of the beds near the top and south-east of Sgùrr na Coinnich — including the lower members of the Kinloch series (Ba^4), part of the Beinn na Seamraig grits (Ba^3), and all the Loch na Dal shales (Ba^2) and the epidotic grits (Ba^1)—are in the upper or reversed limb of the fold, and they show cleavage and other effects of dynamometamorphism in increasing degree towards the south-east.

On Dun Ruaige we find a band of mylonised rocks which appear to have been thrust over the adjacent epidotic grits, and have perhaps been formed from Lewisian gneiss.

The oncoming of the Moine schists and the associated Lewisian gneisses is concealed under the Sound of Skye, but it is probable that these rocks are separated from the Dun Ruaige rocks by another thrust—the Moine thrust (T′)—and that this thrust is itself hidden along the line of section by the fault referred to in the first paragraph of this chapter. The first rocks met with on the mainland are granulitic siliceous Moine schists (M). These are overlaid by a thin band of garnetiferous pelitic mica-schist, which is covered in turn by rocks of the Lewisian Gneiss series (A). A few hundred yards south-west of the line of section a band of highly altered conglomerate-schist comes in between the pelitic schist and the overlying series, and contains at its base pebbles of rocks allied to some of those in this series (see Chapter III.).

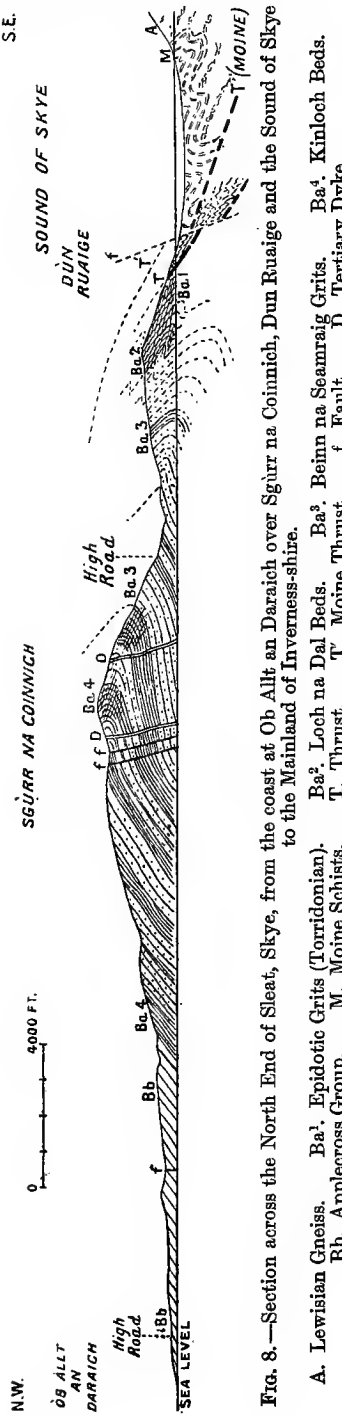


FIG. 8.—Section across the North End of Sleat, Skye, from the coast at Ob Allt an Daraich over Sgùrr na Coinnich, Dun Ruaige and the Sound of Skye to the Mainland of Inverness-shire.

A. Lewisian Gneiss. Ba^1. Epidotic Grits (Torridonian). Ba^2. Loch na Dal Beds. Ba^3. Beinn na Seamraig Grits. Ba^4. Kinloch Beds.
Bb. Applecross Group. M. Moine Schists. T. Thrust. T′. Moine Thrust. f. Fault. D. Tertiary Dyke.

The most striking feature in the next section, Fig. 9, is the emergence of a large mass of Cambrian limestone (Ce and CeVI) from beneath the Applecross grits (Bb). These grits have been pushed

forward from the south-east on a major thrust—the Ben Suardal thrust (T)—which has been folded into an anticline with an axial plane striking N.N.E. and inclining south-east. In Allt Beinn Deirge, nearly a mile north-west of Ben Suardal, a small patch of Applecross grit (Bb), surmounted by the unconformable basal quartzite (Ca), is seen again, resting almost horizontally on Cambrian limestone and separated from it by the same thrust. This thrust plane is also recognisable on the south-eastern slopes of Creag Strollamus, about two miles and a quarter slightly west of north of the place where the line of section crosses Allt Beinn Deirge, so that in this district the breadth of the belt of post-Cambrian complication must be at least nine miles and a half.

The fold which folded the Ben Suardal thrust (T) also folded the Mesozoic rocks (*f*) which circle round the north end of Ben Suardal, and most of the folding * exhibited by the thrust must be later than these beds, for in each limb of the fold they dip almost the same as the thrust. The south-east

* Probably not all, for a little further south-west, on the flanks of Beinn an Dubhaich, Mesozoic beds lie on Cambrian limestones which have been exposed by denudation along the continuation of the anticline.

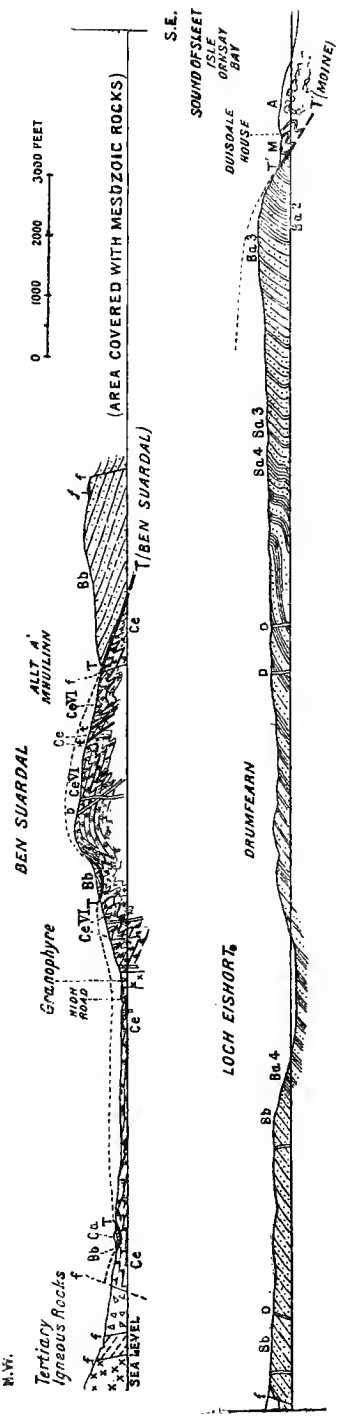


FIG. 9.—Section from the foot of Beinn na Caillich, Broadford, across Ben Suardal, Loch Eishort, and Sleat to Duisdale House, on the Sound of Sleat.*

A. Lewisian Gneiss. Ba^2. Loch na Dal Shales (Torridonian). Ba^3. Beinn na Seamraig Grits. Ba^4. Kinloch Shales. Bb. Applecross Group.
Ca. Basal Quartzite (Cambrian). Ce. Beinn an Dubhaich and Strath Suardal Groups. CeVI. Ben Suardal Group. M. Moine Schist.
t. Minor Thrusts. T. Ben Suardal Thrust. T'. Moine Thrust. *f*. Mesozoic Rocks. f. Fault. D. Tertiary Dyke.

* This section also illustrates a portion of the district to be next described, including Kilchrist, Torran and the Sound of Scalpa.

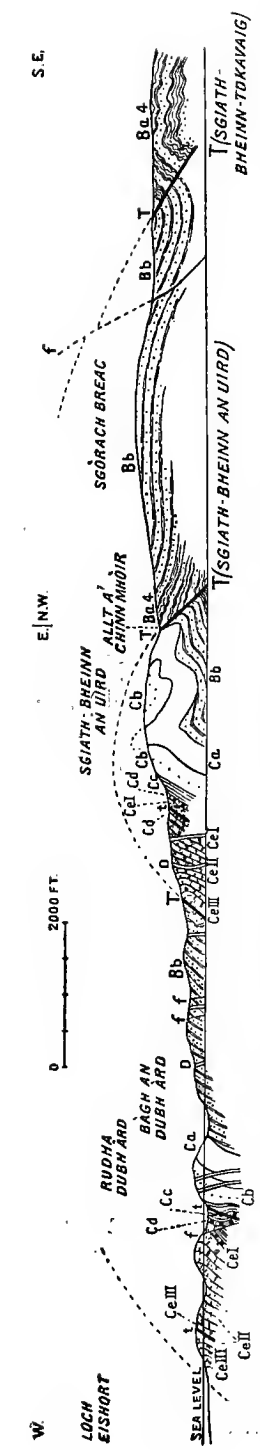


Fig. 10.—Section from Loch Eishort over the North Side of Sgiath-bheinn an Uird.

Ba⁴. Kinloch Beds (Torridonian). Bb. Applecross Group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite Grit. CeI. Ghrudaidh Group. CeII. Eilean Dubh Group. CeIII. Sailmohr Group. t. Minor Thrust. T. Major Thrust. f. Fault. D. Tertiary Dyke.

limb dips in a south-easterly direction generally less steeply than the north-west limb in a north-west direction, and the fold must therefore have been developed by pressure acting from the south-east—the direction from which also the pressure came which gave rise to the great post-Cambrian thrusts and folds.

The south-east limb of the Ben Suardal thrust (T) is broken in places by a fault (f), or several parallel faults, with downthrow to the south-east. The Cambrian limestones are sharply folded and crossed by minor thrusts (t), and it is probable that all of them have been thrust forward on some great thrust which is not exposed.

Most of the rocks outcropping between the Cambrian limestones and the Moine thrust (T′) near the south-east end of the section are Torridonian, but a band of Mesozoic rocks (*f*, left blank in Fig. 9), which were deposited long after the thrust movements ceased, comes in in a syncline. The inclination of the Moine thrust (T′) appears to be unusually steep, but lessens in a south-westerly direction.

The section in Fig. 10 shows two major thrusts (T) which have been folded into anticlines striking N.N.E. The higher one is well seen on the west side of Sgiath-bheinn Tokavaig, a little south of the line of section, and may be called the Sgiath-bheinn Tokavaig thrust. The lower one is nearly always distinct and may be named after Sgiath-bheinn an Uird, a hill composed of rocks lying beneath it. These two thrusts, and the rocks below, are exposed on the south-west or upthrow side of a large fault which runs N.N.W. from Ob Snusaich, in the Sound of Skye, past the west side of Loch an Iasgaich and through Loch an Eilean. On the north-west side of Loch Eishort it throws down the Triassic conglomerates to the north-east, and south-east of this loch it

throws down the older rocks in the same direction, so that neither of the thrusts are seen in the part of Skye lying further north-east.

As shown in Fig. 9, the Cambrian limestones on Ben Suardal also underlie a great folded thrust — the Ben Suardal thrust—the axis of the anticline of which strikes two or three miles further north-west than that of the anticline which affects the Sgiath-bheinn Tokavaig thrust, and possibly the former thrust is a continuation of the latter.

All the rocks exposed along the section below the Sgiath-bheinn an Uird thrust are Cambrian, but, a little further south, Torridon rocks come in, and are sometimes in a reversed condition above the quartzite. More than half the Cambrian area is composed of quartzite which is thrown into folds, often isoclinal, with axial planes inclining south-east.

About half a mile north of the section, along the part of Allt a' Chinn Mhoir which runs north-west, the Sgiath-bheinn an Uird thrust is accompanied by a coarse crush breccia, several feet wide, which is largely composed of blocks of quartzite embedded in a calcareous matrix.

In several places near the north-west limb of this thrust, we find lying over or in the Sailmohr, Eileandubh and Ghrudaidh limestones, masses of a curious siliceous rock (7359 and 7360), parts of which resemble the serpulite grit, while others resemble chert. They do not, however, contain clastic grains, and some of the largest masses, for instance one in the Ghrudaidh limestone half a mile S.S.E. of Sgeir Gormul, occur in horizons of limestone which are normally free from chert. Perhaps they represent a variety of vein-rock, formed by solutions percolating downwards from the formerly overlying thrust-plane.

The section in Fig. 11 cuts the Sgiath-bheinn an Uird thrust (T) and the Sgiath-bheinn Tokavaig thrust (T)

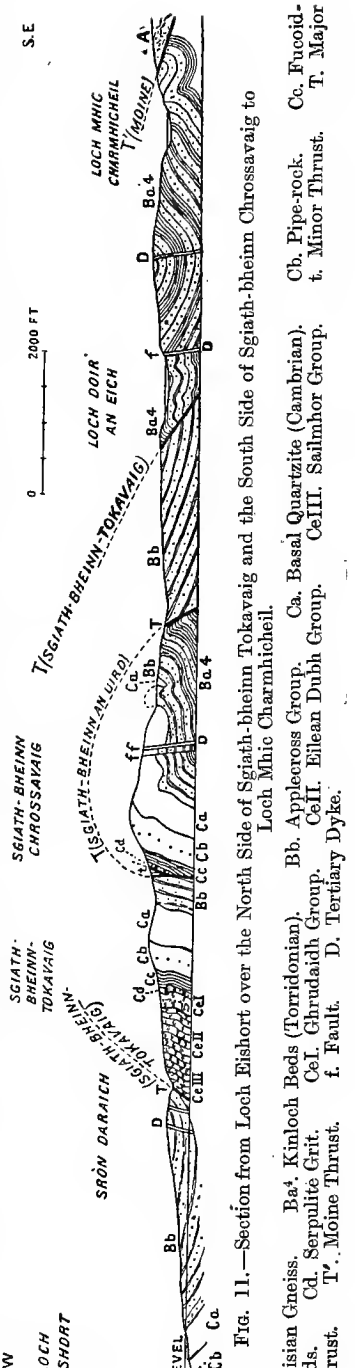


Fig. 11.—Section from Loch Eishort over the North Side of Sgiath-bheinn Tokavaig and the South Side of Sgiath-bheinn Chrossavaig to Loch Mhic Charmhicheil.

A. Lewisian Gneiss. Ba⁴. Kinloch Beds (Torridonian). Bb. Applecross Group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid-beds. Cd. Serpulite Grit. CeI. Ghrudaidh Group. CeII. Eilean Dubh Group. CeIII. Sailmhor Group. t. Minor Thrust. T. Major Thrust. T'. Moine Thrust. f. Fault. D. Tertiary Dyke.

south-west of the last section. The west limb of the former thrust is sometimes reversed, inclining E.S.E. at 70° or 80°, and it might perhaps be imagined that the rocks on the east side have been pushed over those on the west; but it is clear that this is not the case, for the outcrop of the thrust can be traced distinctly at the south-west apex of the anticline, where the quartzite, which forms the greater part of the mass below the thrust, forms a great contrast to the Torridonian rocks which lie outside the apex: the crushed surface of quartzite which marks the thrust in this locality generally inclines south from 26° to 30°.

The Sgiath-bheinn Tokavaig thrust at and near the top of the wood half a mile S.S.E. of Sròn Daraich is marked by the presence of a curious siliceous breccia, at least 10 ft. thick in some places, which in certain localities is full of pieces of banded chert and in others of pieces of white quartzite. The absence of fragments of limestone and of calcareous matter makes it difficult to understand how the chert pieces can have been derived from limestone, and it seems possible that they represent broken up portions of vein-rock. Before they reach the breccia the fucoid-shales thin away almost to nothing, having apparently been squeezed away between the more massive beds.

The basal quartzite (Ca) and the Applecross grits (Bb) exposed in the line of section above the west limb of the Sgiath-bheinn Tokavaig thrust (T) are in a reversed condition, the former dipping below the latter, in some places as low as 18°. C. T. C.

Kilchrist and Torran Areas, and Sound of Scalpa.

The outcrop of the thrust-surface which partly encircles Ben Suardal (Fig. 9) is cut off at the high road by a N.-S. fault, the same which brings the Lias of Broadford against the Cambrian limestones of the strath. A fault on nearly the same line, passing a little west of Loch Lonachan and along Allt na Pairte, cuts off the outcrop of the thrust-surface on the other side of the high ground. The effect here would be to throw the outcrop farther southward on the west side of the fault, and such is the case; but the visible juxtaposition of the Cambrian and Torridonian along this westward line is a normal fault, the overthrust being dropped out of sight. The Torridon Sandstone makes an escarpment overlooking the Cambrian limestones. Farther west a small patch of Cambrian quartzite rests on the Torridonian on the south side of the fault; and then the Mesozoic rocks come transgressively across, concealing the relations below. It is clear that the limestones round Beinn an Dubhaich and about Torran, as well as those west of Broadford and the Strath, are all below the principal surface of overthrust.

The overthrust is, however, proved in numerous places to the west of Broadford, where Torridon Sandstone is seen resting on the Cambrian limestones. Thus, as shown in Fig. 9, a small outlier of the thrust sandstone is exposed for about 100 yds. in Allt Beinn Deirge, just above the principal sharp bend of the burn; and on this in turn rests a very small patch of conglomeratic quartzite representing the unconformable base of the Cambrian. About a mile W.N.W. of Broadford several small outliers of Torridon rest on the limestone,

the surface of the overthrust being often picked out by intrusions of Tertiary granite. Farther to the north-west the Torridonian sandstone makes somewhat larger patches, and, despite the interpolation of the Tertiary intrusions, its relation to the limestones below is often well exhibited. The lower part of Allt Mhic Leanain is a good place to observe this. On the south-east slope of Creag Strollamus the overthrust is again clearly demonstrated, a row of small inliers of limestone below the sandstone being well shown. Here, as before, the surface of junction has in places been invaded by granite.

From the last exposure of Torridonian on Creag Strollamus to the nearest on Scalpa is a distance of only three-quarters of a mile, occupied by Tertiary igneous rocks and the narrow span of the Sound. Even apart from later faulting, the evident irregularly curved form of the surface of overthrust where it can be followed in Skye forbids us to pronounce decisively whether it passes above or below the Torridonian *massif* of Scalpa. It certainly does not pass through these rocks as seen above sea-level. A. H.

If it be the case that all the Torridonian rocks of Scalpa and Longay are in a thrust condition, the thrust on which they lie must make a great bend eastward from the north-west end of Scalpa, or else it must be faulted. It is certain that the Torridonian rocks of the Crowlin Islands and of the adjacent portions of Applecross are all in an unthrust condition. B. N. P.

CHAPTER VII.

PRE-TRIASSIC IGNEOUS ROCKS.

Section I.—The Later Pegmatites in the Lewisian Gneiss and the Pegmatites in the Moine Series. Granite-Gneisses intrusive in the Lewisian Gneiss and in the Moine Series.

The pegmatites and quartzo-felspathic veins in the Moine series are of various forms, being partly in broad straight dyke-like but frequently branching bands, partly in small spots or *augen*, and partly in thin lenticular streaks which keep nearly along the foliation of the rock. Some of the first-mentioned forms can be proved to be later than some of the last-mentioned, and later also than many of the quartz veins and isoclinical folds, and it is rare to find them in a granulitic state. A few, however, which have apparently formed special lines of weakness, have been well foliated and granulitised, as may be seen a little distance north of Bealachachasain, in the adjoining one-inch map 72, and near the top of Beinn Fhada (about a mile and a half south-west of Totaig).

The thinner lenticles and streaks which keep nearly along the foliation, are found both in the psammitic and pelitic rocks, but seem most abundant in the latter. They are often disposed in sharp folds, and sometimes contain quartz in a granulitic condition and are crossed by an obscure foliation parallel to the axial planes of fold; but such cases are rare in comparison to the others in which no indications of foliation or granulitisation exist, so that it seems probable that the pegmatitic material has usually been introduced during or subsequent to the folding. In cases where foliation and granulitisation are found, it is generally only the quartzose parts which are well granulitised, and the foliation is much less perfectly developed than in those pegmatities (within the Lewisian Gneiss) which we suppose to be older than the Moine series (Chap. II.). There are, however, some pegmatites, for instance those in the thick cluster in the Lewisian Gneiss a little north-east of Corrary, the age of which is uncertain.

Both the broad straight pegmatites and the thin lenticular streaks are represented also in the Lewisian Gneiss series, and individual bands of the former class can, in some localities, for instance on the north side of Beinn nan Caorach, be traced from the one series into the other.

Many of the broad pegmatites are represented in the published map, where they will be observed in special abundance near the southern part of the eastern margin, generally striking north-west, and a good many with breadths of 20 or 30 yds. The main areas of occurrence of the thin pegmatitic streaks within the Moine series have also been noted, and in the map these areas are indicated approximately

PSAMMITIC GNEISS OF THE MOINE SERIES. Of the coarse-grained type with pegmatitic veins and lenticles. Western face of Beinn a' Chuirn, three miles north-east of the Kirkton of Glenelg.

by an overprinted pattern. They all lie a considerable distance south-east of the Moine thrust, and in districts where the rocks are much coarser-grained and more gneissose in structure than those which are found close to this thrust, and, as the pegmatitic patches are usually edged with a sheath of rock which is much richer in biotite than the rock further away, it is suggested that they represent segregations derived from the immediately adjoining rock, rather than injections of foreign materials. This suggestion is, perhaps, somewhat strengthened by the frequent occurrence of small pegmatitic spots or *augen*, varying in size from a hazel nut to a duck's egg, which appear to be quite isolated in the rock. Such spots are particularly well seen in the siliceous schists forming the base of the Moine series on the south-west and west sides of Beinn a' Chuirn (Plate XII.); the felspars in these spots are generally free from granulitisation; the cross sections of some spots are formed entirely by one crystal individual, and those of others by a comparatively small number of individuals, some of which (7896) show microcline structure under the microscope. In certain adjoining pegmatitic streaks, however, represented by slide 7897, there is a considerable amount of granulitisation, and it may be concluded that these were introduced before the cessation of the movements which are indicated in the schists.

The broad straight pegmatites vary in composition considerably, the more acid and more basic being connected by intermediate stages. The more acid, which often contain white felspar and a considerable amount of quartz as well as of white mica, are well represented in the Moine rocks near Barrisdale Bay, and in the Lewisian Gneiss near the top of Beinn Fhada. The more basic types, which usually contain red felspar and biotite to the exclusion of muscovite, are in most districts, however, more common than the above. Judging from the examinations made, the felspar in both types generally consists of microcline or microperthite, though some striated felspar, presumably oligoclase, has also not infrequently been detected; it occurs, for instance, in tolerable abundance in a big tumbled block which lies by the roadside near the Manse rather more than a mile up the Glenmore of Glenelg, also in some white pegmatites in the Fraoch Eilean, near Barrisdale, and in others on the coast a little south of this island.

Some rather fine-grained bands of granitic gneiss—mostly of a dyke-like character and striking north-west—occur both in the Lewisian Gneiss and the Moine series, and generally in areas where pegmatites are abundant. They are found in both sets of rocks in adjoining areas on the eastern slopes of Beinn nan Caorach, and most of them are rather fine-grained pink biotite-gneisses of very similar appearance. They have never been seen to pass into an unfoliated condition, and one example, nearly half a mile south-east of the Ordnance Station on Beinn nan Caorach, is in the form of an isoclinal fold, but they frequently contain pegmatites which show no clear foliation and which are indistinguishable from other pegmatites outside them. One band, in a considerably pegmatised condition, on the north-eastern slope of Beinn nan Caorach, attains a width of 150 yds., but this is exceptional, and most of those in the same locality are not more than 10 or 20 yds. broad. On the east side of

Barrisdale Bay a few thinner dykes are seen, which also strike north-west.

Some of these granitic gneisses cut the broad banding or bedding of the adjoining rocks distinctly, but their foliation planes occasionally strike against their sides and have the same directions as the foliation planes of the rocks which are cut. A good example of this last phenomenon is seen in a thin, almost horizontal, pink sheet, which is exposed rather more than half a mile north-east of the lochan in Coire Min (east of Ben Sgriol); in this locality the Moine rocks dip steeply to the east, and the granitic rock cuts them and also many of the quartz veins. In the same locality, nearly two-thirds of a mile N.N.E. of the lochan referred to, a thinner pale grey granitic streak also runs nearly horizontal, and contains white mica as well as black.

Section II.—Basic Schistose Intrusion in the Moine Series.

A basic partially foliated intrusion has been traced in a S.S.E. direction from the southern side of Poll a' Mhuineil (south side of Loch Hourn) for about half a mile, and may extend considerably further. It forms a nearly straight almost vertical band, usually marked by a narrow depression on the hillside, which runs approximately parallel to the strike of the adjoining schists, and is slightly thrown by two faults. The average breadth is probably only 5 or 6 ft. In some exposures there is no clear foliation, but in others certain parts are well foliated parallel to the side. The unfoliated portions vary considerably in composition, some being rich in felspar, of a white colour, while others are mainly composed of small needles of pale hornblende or of these mixed with chlorite. Specimen 9121 is a hornblende-chlorite-rock allied to scyelite. It seems tolerably certain that the neighbouring Moine rocks were in a schistose condition before this basic band was intruded, and that it formed a line of weakness along which subsequent schist-making movements took place.

Section III.—Newer Igneous Rocks.

Glenelg-Ràtagain complex.

After the Lewisian Gneiss and the Moine rocks had been folded and invaded by pegmatites, and had acquired nearly all their present characters, they were pierced by a series of intrusive rocks forming the Glenelg-Ràtagain igneous complex. Of this complex only the western portion, the area of which is about three square miles, is contained within the one-inch map 71, near the head of Glenmore of Glenelg, where the ready disintegration of most of the component rocks has given rise to unusually smooth and grassy features, as is shown in the foreground of Plate XIII. The main mass of the complex is surrounded on the western side by a broad fringe of smaller allied masses, and the margins both of these and the main portion are very jagged and quite unchilled.

In the field, we have, with the aid of many specific gravity determinations, divided the rocks into three main groups, but each of these

VIEW FROM ROADSIDE A LITTLE EAST OF ACHADHACHUIRN, three miles east of the Kirkton of Glenelg. The low smooth slopes are composed of diorite or other igneous rock of the Glenelg-Ratagain complex. The hills along the sky-line are chiefly composed of Moine schists; they bear the following names, in order from left to right, Sgurr Mhic Bharraich, Sgurr a' Gharg Gharaidh, The Saddle (3317 feet).

in certain places passes gradually into one of the other groups, and each also includes several varieties which graduate into one another. The groups are as follows, in order of increasing basicity :—

A. Biotite-granite or Granitite. Biotite-hornblende-granitite. Pale Syenite.
B. Quartz-diorite or Tonalite. Dark Syenite. Augite-syenite. Mica-augite-diorite.
C. Pyroxenite, Biotite-pyroxenite, Hornblendite.

Group B covers much the largest area. Near the western edge its more basic types seem to pass gradually into tonalite, and still further west this in turn into hornblende-granitite or granitite. Many of the thin ramifying strings which pierce the schists and gneisses in the neighbourhood of certain masses of diorite or dark syenite, and which seem to be offshoots from these masses, contain less hornblende and more quartz than these masses, and perhaps some siliceous material derived from the schists etc. may have been incorporated into their substance. The hornblendes in the group are usually idiomorphic, but somewhat small, while the felspars, which sometimes form individuals as much as an inch broad, are frequently poikilitic with inclusions of hornblende.

Indications of flow structure are very abundant, particularly in group B. In certain places, as in Allt Cnoc Fhinn on either side of the bridge, thin parallel stripes of different colour and grain and no more than an inch or two thick, follow one another in close succession, and are associated also with inclusions of darker more basic rock, the longer axes of which are also parallel. These stripes are sometimes crossed by short strings of granite or granite-porphyry, which are very irregular in direction, have no chilled margins, and are traversed by the same joints as the neighbouring rock.

A pale pink band with hardly any ferromagnesian constituents is found, within darker syenite and diorite, on the east side of the bridge over Allt Cnoc Fhinn, and is traceable thence in a northerly direction for nearly half a mile. Near the bridge it is about 50 yds. wide, but at the east margin it seems to pass gradually into the darker rocks, and on the west it is also mixed with dark parallel bands. A specimen (9800) from near the road proved, on microscopic examination, to be a syenite composed principally of perthitic alkali felspars, and is said by Dr. Flett to have a considerable resemblance to the Nordmarkite of Brögger. Various other bands with a macroscopic resemblance to this have also been noticed, *e.g.*, one just east of it near the road, another near the head of Allt Cnoc Fhinn, and various seams mixed with parallel darker bands in a burn section about a quarter of a mile east of the map margin, and nearly the same distance south of the road.

The granite or granitite, into which the rocks of group B seem gradually to pass at their western margin, is frequently associated with and intersected by thin irregular veins of eurite or fine-grained pegmatite. In places it contains porphyritic crystals of orthoclase as much as an inch long, and is generally slightly coarser in grain and contains somewhat more ferromagnesian constituents than the granitic rocks which occur further east. These eastern rocks only come into one-inch map 71 in two small patches near and south of the county boundary, but they form a considerable mass extending

further east past Bealach Ràtagain to Loch Duich. They are of a pink colour, and some varieties differ but slightly from the syenite at the Allt Cnoc Fhinn bridge, excepting perhaps in being slightly richer in quartz. They are often seen to intrude into and include portions of rocks belonging to group B—behaving in this respect in a very different manner from the western granite—but are never chilled against them.

The rocks of group C are not largely represented, but they compose the greater part of four small patches near Suardalan. These rocks, the most basic of the complex, were also no doubt the first to consolidate, for in one place they are clearly invaded by rocks of group B, and they, or closely allied varieties, have been the source of numberless inclusions found within the rocks of this group. Such inclusions are well seen in the burn flowing past Suardalan, but better still in a burn about a mile S.S.W. of Druim Sgùrr nan Cabar (one-inch map 72), where over considerable areas the inclusions bulk almost as largely as the enclosing rock. Many of the rocks of this group are distinguished by the presence of large poikilitic flakes of brown biotite, enclosing pyroxene, and most of them contain small amounts of orthoclase as well as plagioclase, a somewhat surprising feature which helps to show their genetic connection with the other rocks of the complex. No olivine has been detected.

In certain places the rocks of groups A and B have been considerably sheared and granulitised in numerous narrow stripes, the average direction of which is slightly south of west, but most of these are found within the one-inch map 72. A good example, about 2 ft. thick and striking east and west, occurs, however, very near one-inch map 71, in the diorite in the burn nearly a quarter of a mile slightly north of east of Suardalan.

In certain localities, as, for instance, between 700 and 840 yds. south-east of the Ordnance Station on Beinn a' Chaoinich, the schists and gneisses next the intrusions have been converted into a breccia formed of fragments of different sizes and shapes, separated by thin strings of biotite-granite. The banding in adjacent fragments often differs greatly in direction, but the strings are usually so thin in comparison to the breadths of the fragments, that it is difficult to see how these last can have been moved about so much as is suggested.

A marked deviation of strike, from the common N.N.E. into a nearly east and west direction, is noticed on the south and south-west sides of the complex, but it extends more than four miles from these sides, and is perhaps best explained as the results of lateral thrusting along the Ben Sgriol faults (Chap. XIV.).

In some of the neighbouring Lewisian gneisses, chlorite seems to have been converted into black biotite in consequence of a metamorphism exerted during the intrusion; but most of the rocks next the complex are siliceous Moine schists, which seem to have been already so greatly altered by an earlier metamorphism, that they did not admit of any further appreciable change.

DYKES AND SILLS.

The dykes and sills now to be described are often cut by the Tertiary dykes—as is well seen in the southern slopes of Ben Aslak—

and are also frequently crushed and displaced by faults. They may perhaps be referred to the later portion of the great period of intrusion to which the Glenelg-Ràtagain plutonic rocks belong, though they often cross and are chilled against them; no less than fifteen, for example, traverse the diorite and syenite of Allt Cnoc Fhinn in a breadth of less than 700 yds., but only some of these are shown on the published map.

Most of these intrusions are in the form of nearly vertical dykes, sheets or sills being somewhat uncommon. They are best developed on the mainland between Loch Alsh, Loch Duich and the Glenmore of Glenelg, being in this area decidedly more numerous than the Tertiary dykes, and sometimes as much as 20 or 30 yds. in breadth; their general direction is W.N.W., and occasionally two or more run in contact for short distances in the form of multiple or composite dykes. Between Glenmore and Loch Hourn they are less abundant than to the north, and the direction is most often nearly east and west and sometimes slightly south of west. South of Loch Hourn they also have a nearly east and west direction, but are rare.

When we proceed in a W.N.W. or west direction along the strike of the dykes, from the mainland across those parts of Skye which are composed of pre-Triassic rocks, these intrusions appear gradually to decrease in number, and in the Torridonian rocks between Lusa and Boreraig very few have been observed.

They are composed of rocks of many lithological varieties, among which are the following: quartz-felsite, felstone, biotite-porphyrite, hornblende-biotite-porphyrite, vogesite and minette, together with others which are considerably decomposed and can only be classed as lamprophyres, diorites, or mica-traps. But of all these, the porphyrites are much the commonest. The dykes of the different types generally keep nearly the same direction, and intrusions of one into another are not often observed. Some sections have, however, been noticed in which the more acid dykes are pierced by more basic types, and we suppose that the usual rule prevails, according to which, among the intrusions belonging to the dyke-phase of any particular period, the more basic rocks are generally the later. A good section of this kind is seen rather more than two-thirds of a mile E.N.E. of the Ordnance Station on Glas Bheinn, where a mica-trap with chilled margins is found in the middle of a dyke of quartz-felsite. In another section, about half a mile south-west of Lochan an Liath-truisg (north-east side of Beinn a' Chuirn), a cream-coloured quartz-felsite is cut by a pink biotite-porphyrite. But occasionally we meet with apparent exceptions to the rule, as, for instance, near the burn about half a mile east of Lochan an Liath-truisg, where a biotite-porphyrite seems to be later than a dark mica-trap running north-east.

Xenoliths are in general more common in the rocks of this group than in the Tertiary dykes, and in one broad east and west dyke (to be classed, perhaps, as a mica-trap), in the river about a mile slightly north of west of Strathchomair, they make nearly half the mass.

The porphyrite intrusions usually contain somewhat prominent phenocrysts of felspar, which are generally paler than the matrix, and are zoned and show distinct plagioclase twinning. The matrix

is generally pink or brick red in the interior, but often becomes dark brown or purple near chilled margins.

The quartz-felsites and felstones vary in colour from pale buff to pink, and often show very beautiful flow structures at their sides, for examples of which we may refer to the felstone sheets on the coast between Port a' Gharaidh and Rudha a' Chamais Bhàin.

In the mica-traps apatite is generally abundant, and can sometimes be discerned with the naked eye. It is occasionally noticed that the biotite flakes continue up to the margin, and that in positions near it they are arranged in close parallelism therewith, in consequence of a flow structure. An augite-minette (8665) on the coast close to Eilean a' Chlamhuinn (mouth of Loch Hourn) contains pseudomorphs after olivine and seems allied to the kentallenites, the ground mass being apparently composed of potash felspar to a large extent.

A thin dyke (represented by specimen 5073) on the coast about 300 yds. south of Rudha na Caillich (north end of Kyle Rhea) may perhaps be classed with the teschenites, as it contains numbers of small ill-defined spots which on microscopic examination are seen to consist of some isotropic substance, resembling analcime, in which felspar microlites and needles of hornblende are embedded.

Along the course of the Moine thrust in Allt Bealach na Coise, there is a sheet of decomposed mica-trap which has in most parts been greatly crushed and converted into a fine clay by movements along the thrust-plane. It seems probable that the plane has been a scene of earth movements at different periods, and that the mica-trap has taken advantage of it as an earlier plane of weakness.

C. T. C.

On the mainland north of Loch Alsh, a few small dykes of mica-trap are found cutting the Lewisian Gneiss east of the Moine thrust in the area between Kirkton of Lochalsh and Ardelve. These are well exposed on the shore round the headland of Avernish and beyond the mouth of Allt Gleann Udalain. Some examples also occur intersecting the crushed gneiss on Beinn Raimh and about a mile further north.

B. N. P.

CHAPTER VIII.

TRIAS OR NEW RED SERIES.

Broadford and Heast District.

In this district the Trias or New Red series is composed of red and variegated shaly marls, red and greenish sandstones, and beds of conglomerate, containing many pebbles or boulders of Torridon sandstone, quartz, quartzite and Durness limestone, especially of the Eileandubh zone. It forms a thin, considerably faulted rim on either side of the syncline of Mesozoic rocks, which extends south and south-west from Harrabol, Broadford, towards Boreraig. It also spreads round the northern end of the Ben Suardal anticline, and continues along the north-west of this fold for a mile or more.

The total thickness appears to be very much less than that found in some parts of the Highlands.* In the southern part of the district being described, it probably does not exceed 50 ft. The conglomerate is well shown in the burn Allt a' Mhuilinn, above the Broadford Corn Mill, and occurs again to the west and south-west towards Strath Suardal. Its position above the Torridon sandstone and below the Lias was so far recognised by Macculloch that he remarked on it as "probably situated between the sandstone and the limestone." †

A belt of Red rocks appears at Skulamus and borders the main road from Upper Breakish to the burn Abhuinn Ashik near Lusa (Lussay), forming a gentle escarpment above the more broken ground of the Torridon Sandstone. In this neighbourhood they comprise red shale and sandstone, and conglomerate. The conglomerate here and there contains thin veins of siliceous material, to which our attention was called in 1893 by Professor G. A. Lebour. The material resembles that of the larger bands of "cherty rock," at Golspie in Sutherland, and Stotfield near Lossiemouth in Elgin; a fact of interest when we compare the Red rocks of Skye with those of the north-east of Scotland. The Stotfield rock was described by Professor Judd as calcareo-siliceous, altogether destitute of organic remains, and probably due to purely chemical agencies; ‡ and the appearance of the veins in the New Red rocks of Skye would favour the view that the siliceous material had been introduced by heated waters. H. B. W., C. T. C.

Along the eastern side of the syncline just referred to, in a locality a little south-east of Druim Bhàin, three miles S.S.E. of Broadford, red and green marl, not exposed for some distance further north,

* Prof. Judd ("The Secondary Rocks of Scotland," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 688) estimated the thickness at Gruinard Bay, Ross-shire, at more than 1000 ft.

† "A Description of the Western Islands of Scotland," 1819, vol. i. p. 326.

‡ "The Secondary Rocks of Scotland," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. pp. 135, 136.

underlies the pebbly base of the Jurassic. Lower conglomerates contain Torridon sandstone and Durness limestone. A similar sequence persists to Heast, where Mr. Barrow records the following succession, sharply marked off from the overlying Passage-beds, in and near Allt an Daraich, below the road :—

	Thickness. Ft.
Marl, greenish at top, rapidly changing below to reddish, with concretionary patches of green and red sandstone, passes down to	about 2
Fine hard greenish sandstone, becoming amygdaloidal and calcareous below	about 3
Greenish marl, changing to red, and passing into a chocolate sandstone at its base	4
Detrital limestone, mainly inorganic	1
Green and mottled marl	3
Green sandstone a few feet thick	—
Conglomerate	—

Mr. Barrow states that the conglomeratic Trias at Heast, mostly quartzose, includes lenticles of calcareous conglomerate and some beds of sandstone, with a persistent band of marl at the top. It thins south-westward, and dies out near the coast,* beyond the fault west of Beinn a' Chàirn. Thence the conglomerates thicken rapidly northward.

Similarly, red and green marl, merging into sandstones and conglomerates below, continues along the western side of the syncline southward to Loch Buidhe. There a line of little shallow pools marks the position of upper soft red sandy shales and mudstones. Lower beds of indurated red and buff marl, full of Durness limestone pebbles with some of Torridon sandstone, overlie hard sandy conglomerates, and betoken an approaching change in the Trias. West of Loch an Eilean, too, conglomerates of Durness limestone and quartz pebbles, with a little Torridon sandstone, in a sandy or marly matrix, occur amongst the red marls, with red sandy conglomerate of these pebbles at the base. But north-west of Loch Braigh Bhlàir, the conglomerates have a calcareous matrix full of Durness limestone and chert. At the top of Glen Boreraig, apparently the whole thickness of the Trias consists of some 40 ft. of a breccia-conglomerate with a blue limestone matrix containing thin bands and irregular patches of red marl. The rock is crowded with angular and rounded blocks and pebbles of Durness limestone, white quartzite, Durness chert, vein-quartz, and a few of Torridon sandstone and coarse white grit, in order of decreasing abundance. Sir A. Geikie has described and figured an exposure of this breccia resting with a striking unconformability on the Durness limestone further west in the glen of Allt Lèth Slighe, estimating its thickness at 50–60 ft. shortly before it is overlapped.† Half a mile from the coast the Lias comes to rest directly upon the Cambrian limestone.

The development of a limestone-conglomerate first in the red marl, and the presence of streaks and patches of red marl in this extreme calcareous type of the Secondary basement beds, suggest

* See (Sir) A. Geikie, "On the Age of the Altered Limestone of Strath, Skye," *Quart. Journ. Geol. Soc.*, 1888, vol. xliv. p. 72.

† *Op. cit.*, p. 71.

that the latter represent the Trias of the rest of Strath rather than a conglomeratic phase of the Liassic limestones.

The Trias overlies Torridon sandstone from Broadford southward beyond the head of Glen Boreraig, though never far distant from the tract of Durness limestone. But its most calcareous development comes on gradually, and only reaches its maximum on approaching close to the outcrop of the Cambrian limestone.

The quartzite pebbles in the conglomerate of Glen Boreraig are probably derived from the white Cambrian quartzite there represented by a faulted patch. C. B. W.

The Applecross grits composing the pre-Triassic surface are in places considerably jointed, weathered and stained Indian red. Near the bridge across Abhuinn Ashik, about three miles east of Broadford, and in another position, nearly 600 yds. north-east of the outlet of Loch Buidhe, these grits are also crossed by many irregular calcareous streaks and veins of limestone, the substance of which has no doubt been derived from the overlying calcareous Triassic conglomerate. C. T. C.

Scalpa.

An isolated occurrence of Triassic conglomerate is found in the north-western corner of the isle of Scalpa, resting on Torridonian sandstones. It forms the low hill above Rudha Chinn Mhòir, a patch about 500 yds. in length, and also the little islet to the east, named Eilean Leac na Gainimh. The beds exposed have a total thickness of over 100 ft., and dip north-westerly into the sea at angles up to 30°. The pebbles in the conglomerate range up to six inches or more in diameter, and include Torridonian sandstones, Cambrian limestone and chert, quartzite and quartz. Here, as elsewhere in the Triassic conglomerate of the region, the Cambrian limestones are not dolomitised. The pebbles are mostly well rolled, but some are sub-angular. A. H.

Raasay.

The New Red rocks consist of red and mottled sandstone with calcareous nodules, and of conglomeratic layers with pebbles of quartz, schist, Torridon sandstone and Durness limestone. Some of the sandstones are very coarse in grain. These beds which have a general dip to the north-west are seen to the north of Rudha na Cloiche, along the borders of Eyre Burn and Eyre Cliff, and whether in cliffs or scarps they recall to mind the Red rocks of Devon and Somerset. Some of the pebbly sandstones are calcareous, and they weather in cavernous form, a feature in part due to the weathering out of pebbles. Elsewhere the matrix of the conglomerates is washed away from exposed faces of the rock. About one-quarter of a mile north of Rudha na Cloiche a basalt dyke, 1 ft. 6 in. to 3 ft. wide, traverses the conglomerate in a direction 15° N. of W., and where broader it contains quartz and other pebbles derived from the conglomerate.

Many small dykes traverse the rocks, some vertical, others inclined and curved. As a rule, they are hollowed out in the cliffs, as the

rock is much jointed and breaks away. The Red Rocks do not appear to be shifted, nor are they altered to any extent. Springs are thrown out in places along the fissures, and by the boulder clay, where it is banked up against the strata.

The general sequence appears to be :—

New Red Series.	Thick masses of conglomerate, and occasional sandstone	30 to 35 ft.
	Red and mottled sandstone with calcareous nodules and pebbly layers	20 to 25 ft.
Torridon Sandstone.		

H. B. W.

Loch Sligachan District.

Red or white conglomerates and sandstones and red or green shaly and loamy marls are separated by certain thin passage-beds from the Liassic limestones. The base of the lower series seems to be always a conglomerate of quartz, Durness limestone and Torridon sandstone, sub-angular or imperfectly rounded, in a sandy matrix, usually red, but sometimes white or buff, where indurated by igneous intrusions. Brick-red or light green marls, often baked buff or white, predominate in the upper part. At the top a compact fine-grained green sandstone sometimes passes down into red marl, but its relation to the passage-beds was not seen. Lenticles of conglomerate with limestone and quartz pebbles in a marly or sandy matrix are developed also in the higher marls, which may contain as well a bed of light creamy grey unfossiliferous limestone. The total thickness probably does not exceed 50 ft. C. B. W.

Tarskavaig District.

Three-quarters of a mile north-east of Tarskavaig Point, a small outlier of conglomerate, about 300 yds. long, rests on an even plane of denudation, sloping gently north-west, which has been formed out of the steeply inclined shales and grits of the Kinloch series of the Torridonian formation. For several hundred yards around the outlier these beds are also stained Indian red or purple. The conglomerate is chiefly formed of well-rounded pebbles and boulders of Cambrian quartzite, belonging partly to the "pipe-rock," and partly to the lower division, which are stained red at the outside, and occasionally attain a length of 9 ins. Mixed with these we find also a few other pebbles of chert, red or black, Durness limestone (Eileandubh zone) and Torridonian grit. The matrix is generally a soft grit of a pale brown or pale grey colour, but in some places it is calcareous, or passes even into a limestone. The whole outlier is riddled with Tertiary dykes, and both it and the neighbouring rocks are considerably altered in places. In certain localities these neighbouring rocks are traversed by cracks and joints filled with streaks of limestone, derived no doubt from the unconformable rocks which formerly overlay them. Such streaks are well seen at the cliff top 330 yds. W.S.W. of the Ordnance Station 282, where they are often an inch or two thick and so numerous that for a depth of four or five feet from the ground surface they are nearly equal in bulk to the shale in which

they occur ; most of those in this locality are nearly horizontal, and cut the bedding of the steeply inclined Kinloch beds at about 40°.

Sgeir Fhada and Sgeir Biodaig, the outermost islands in Tarskavaig Bay, are composed of conglomerate and various Tertiary dykes, and the Kinloch shales and grits on the island east of Sgeir Fhada are also partly stained a deep Indian red colour. The conglomerate is chiefly composed of well-rounded pieces of Cambrian quartzite, often from three to five inches in diameter, with a sparse softer matrix, sometimes red and gritty, but in other places greenish grey and calcareous or passing into limestone. The dip in Sgeir Fhada is slightly west of north at 17°. C. T. C.

CHAPTER IX.

PASSAGE-BEDS (RHÆTIC?).

Broadford and Heast District.

The Passage-beds between the Trias and the Lias are of considerable interest, but as they are probably nowhere more than a few feet in thickness, they are too insignificant to be represented separately on the one-inch map.

There is a conformable and practically unbroken series of strata from the Red Rocks of Lusa and Upper Breakish across the Lower Lias of Ob Breakish to Ardnish; and this succession is continued, though probably not without interruption and repetition by faults, in Pabba and onwards to the Middle Lias in Scalpa. This general sequence was indicated by Macculloch and Murchison, and fully established by Sir Archibald Geikie more than fifty years ago.*

In Ob Lusa (Lusa Bay), the New Red series is much restricted in thickness, if not partly cut out by a fault; but the outcrop is obscured by beach-accumulations, so that we see no reefs of rock between the Torridon sandstone on the east and the Passage-beds at the base of the Lias on the west. In this bay the Passage-beds come immediately below the strata belonging to the Broadford Beds of the Lower Lias, which are shown in a section near the beginning of Chapter X. The Passage-beds are themselves represented by the following section, beginning at the top:—

	Ft.	In.
Pale grey compact limestone, somewhat sandy at base and ? oolitic: rough honeycombed rock	4	0
Pale sandstone with blue limestone nodules		7
Soft, slightly calcareous, reddish and grey sandstone		—

In 1899, Mr. David Tait obtained from the top band of these Passage-beds, from a depth of about 8 ft. below the Lusa coral bed (5 or 6 ft. below the line taken as the base of the Lower Lias), the following fossils, named as far as was possible by Dr. F. L. Kitchin:—

Cerithium semele? *J. Mart.*	Mytilus sp.
Natica? or Nerita?	Ostrea sp.
Myophoria?	Pleuromya?

Cerithium semele, as described by Jules Martin,† ranges from the zone of *Pteria contorta* to that of *Coroniceras bucklandi*. The other genera all occur in Rhætic beds.

Hugh Miller in his "Cruise of the Betsey" ‡ described various beds in Lusa Bay section. Speaking of the lower beds, he states: "They are

* "On the Geology of Strath, Skye," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. p. 5 and plate i.

† "Pal. Strat. de l'Infra-Lias, Cote d'Or," *Mém. Soc. Géol.*, France, 1863, tome vii. p. 75 and plate ii. fig. 8.

‡ Reprinted from articles in the *Witness* newspaper, and edited by the Rev. W. S. Symonds, 1858, pp. 143–147.

composed of greenish-coloured fissile sandstones and calciferous grits, in which we meet a few fossils, very imperfectly preserved." Apparently he found these specimens in the Passage-beds from which elsewhere we have recorded the occurrence of similar poorly preserved fossils.

The Lusa Passage-beds would strike towards the W.S.W., following the Lusa Burn in that direction to the bend north-west of Drochaid Lusa. The ground on the left bank of the stream is, however, obscure at the point where the Passage-beds would be expected to outcrop.

Lower Lias limestones and sandstones, with a north-west dip, are exposed to the north of the stream near the bend; and red conglomerate is to be seen to the south, beneath the valley gravel a little north-west of Drochaid Lusa.

Again along the burn Abhuinn Ashik, the Red Rocks are exposed to the north of the high road, but the junction with the Lias further on is obscured by alluvial ground.

The Red Rocks appear south of Skulamus, and in the low ground east of Braigh Skulamus; but the Passage-beds are nowhere exhibited in these areas. H. B. W., C. T. C.

The sequence between the Red Rocks and Lias is shown on the north-eastern side of Heast, where the Allt an Daraich descends a scarp formed by the Passage-beds. Unfortunately the face of rock is precipitous, and the stream tumbles over it in such quantity as to impede examination. The strata exhibited are as follows :—

		Ft.	In.
Lower Lias	Sandstone, along bed of burn above cascade	—	
	Limestones with traces of coral-structure	3	0
Passage-Beds (Rhætic ?)	Compact limestones with shaly partings	3	3
	Concretionary beds of limestone and calcareous sandstone	3	0
	Greenish slightly calcareous grit	0	3
Trias or New Red Series.	Variegated micaceous shaly marl Hard greenish sandstone	5	0

A search for fossils in these strata was made in 1899 by Mr. David Tait, and from them he obtained a fish scale, specimens of *Ostrea*, and some doubtful plant-remains. Working also in equivalent strata at Allt a' Mhuilinn, above the Broadford Corn Mill, he there obtained casts of lamellibranchs, one of which was recognised by Dr. Kitchin to be near to *Myacites escheri* Winkler.* H. B. W.

Further exposures were subsequently observed by Mr. Barrow, who completed the survey in the Heast area, and supplies the following details. The band of pale buff limestone, representing the top band of the Passage-beds in the above section, is of a tolerably persistent character, but is regarded by Mr. Barrow as the base of the Lower Lias rather than one of the Passage-beds, as it can be traced laterally into pebbly sandstone, which is inseparable from the basal pebbly sandstones of the Lias. In the tract between Heast and Loch Eishort, the above-mentioned limestone rests sometimes directly on Triassic marl without the thin and variable beds that usually intervene. West of the section in Allt an Daraich, near a fault which brings these strata above the road, a remarkable sequence was seen in Allt na Heast. Two feet of calcareous marly shale and marl overlies 10

* See Dumortier, "Études Pal. Dep. Jurass. Bassin du Rhone," 1864, pt. i. p. 14, plate i. fig. 6.

or 12 ft. of slightly calcareous sandstone; between this and a conglomerate assigned to the Trias is a wedge-shaped mass, more than 10 ft. thick in one place, and consisting of a rather nodular sandstone above, with little lenticles of coal and shales below. A little further south the pale buff limestone was traced along the bank, with a thickness of 5 ft., and indications of the green marl of the Trias not more than 3 ft. lower.

The pale buff limestone near here begins to vary, with a mingling of cherty material, while its lower part contains decidedly larger pebbles, and suggests the calcareous conglomerate a little further west (see next paragraph).

Beyond the fault running west of Beinn a' Chàirn, Mr. Barrow remarks that all beds below the typical Lias limestones tend distinctly to diminish south-westward, and near Boreraig a thin conglomerate, frequently of limestone, partly replaces the normal Passage-beds. Near Heast a little calcareous lenticle with *Gryphæa* is enclosed in the conglomerate, and shows its connexion with the Lias. A persistent band of marl separates this conglomerate from those of the Trias, until the latter dies out south-westward.

On the western outcrop of the Jurassic, the Passage-beds, not distinctly seen except in Allt a' Mhuilinn, disappear southward in the overlap.

Loch Sligachan District.

Thin intermediate beds between the Trias and the Liassic limestones, as at Heast and elsewhere, suggest a representative of the Rhætic,* especially by the occurrence of *Pecten valoniensis*.

Below the typical blue limestones of the Lower Lias a bed of small oysters in limestone or calcareous shale is often associated with thin green sandstones and dark shales. Sometimes a coarser-grained bluish-green streaky calcareous grit or a band of creamy buff limestone appears below.

The best section of these Passage-beds is at a small waterfall in Eas Mòr :—

Section in Eas Mòr, Sconser, at waterfall about 400 *yds. from the road.*

		Thickness. Ft.	In.
Lower Lias	Blue limestone with *Gryphæa*	—	
Passage-beds (= Rhætic ?)	Porphyritic sill, about	10	0
	Black shale, about	1	8
	Light green sandstone .. .. .. 1 in. to	0	2
	Black shale	0	7
	Hard light green sandstone with *Pecten valoniensis* ..	0	2
	Calcareous shale full of small *Ostrea*	0	4
	Dark blue sandy limestone with shaly partings and shells	2	0
	Hard fine-grained green sandstone	0	2
	Blue shale	0	2
	Dark green basic sill	1	6
	Black laminated shale	0	8
	Blue limestone with shaly partings and small *Gryphæa* †	2	0
	Gap representing about	7	0
Trias	Red and light green marl, partly baked to a buff colour	—	

C. B. W.

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 142.

† For the occurrence of *Gryphæa* in the Passage-beds at Heast, see description of the Broadford and Heast District.

RAASAY.

The basement beds of the Lower Lias consist of hard compact blue limestones, not unlike in texture the "Sun bed" which occurs on top of the Rhætic Beds in the West of England. Between these basement beds and the New Red rocks the ground is usually obscure, owing, no doubt, to the fact that the intervening strata are comparatively soft.

Working upwards along Eyre Burn the stream is found to cross Torridon Sandstone, and higher up New Red Sandstone; and about a quarter of a mile from its mouth, there is a cascade where the burn falls over ledges of the New Red rocks. Still higher the basement beds of Lias, hard blue limestones, with indurated shaly bands, as at Suisnish, were exposed, and beneath them the following beds were noted in 1893 :—*

Bluish-green shaly limestone with *Modiola* and *Pecten*.
Fissile blue shaly limestone with *Ostrea* and *Pteria*?.
Hard flaggy greenish-grey micaceous sandstone.
Buff shaly and micaceous sandstone, alternating with red micaceous clayey sandstone about 15 ft.

From the specimens then collected, and which were submitted to Mr. E. T. Newton in 1901, he recognised *Pleuromya* cf. *crowcombeia*, as well as *Modiola* and *Pecten*. So far as could be judged, these intermediate beds between the blue compact Lias limestone and the Red beds were about 15 ft. thick. The strata were exposed partly in ledges over which the waters were rushing, and partly in a low bank bordering the burn, which is much overgrown with bushes. It was not possible to note a clear and continuous section—but that there are here passage-beds between the New Red rocks and the Lias, admits of no doubt. It is the only section on Raasay where such beds were exposed, and has not been before noted. The occurrence of New Red beds, both higher up and lower down, is accounted for by the fact that there is a fault.

Thus higher along the burn, and just below the waterfall, there is a descending series of

Red sandstones.
Pale fine calcareous conglomerate.
Red and green calcareous sandstone.

H. B. W.

* In the notes on Skye published in the *Ann. Report of the Geol. Survey* for 1896, p. 69, the fact was overlooked that fossils had been found by the writer in these Passage-beds in Raasay three years previously.

CHAPTER X.

JURASSIC.

When the Lias of the district of Strath in Skye was first described in detail by Sir Archibald Geikie, the fossils he collected were named by Dr. Wright.*

The beds at Lusa were then referred to the Lower Lias (basement portions), the Pabba Shales to the zones of *Ammonites jamesoni*, *A. ibex*, and *A. davoei* (then grouped as Middle Lias), and the Scalpa Beds to the zones of *Ammonites margaritatus* and *A. spinatus* (classed as Marlstone).

During the progress of the geological survey, it was suggested in 1896 that the name Broadford Beds be applied to the lower division of sandstones and limestones equivalent to the Blue Lias limestones of England, which include the zones of *Ammonites planorbis* to *A. semicostatus*.† The present grouping would therefore stand as follows :—

Ammonite Zones.

Middle Lias.	Scalpa Beds.	Spinatus zone.	
		Margaritatus zone.	
Lower Lias.	Pabba Shales.	Capricornus zone.	
		Jamesoni zone.	
		Armatus zone.	
		Raricostatus zone.	
	Broadford Beds.	Obtusus zone.	
		Semicostatus zone.	
		Bucklandi zone.	
		Angulatus zone.	probably represented in time by basement beds.
		Planorbis zone.	

No Upper Lias has been met with in the immediate area under consideration.

Lower Lias.

INTRODUCTION.

The subdivisions of the Broadford Beds which form the lower portion of the Lower Lias, are as follows :—

* "On the Geology of Strath, Skye," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. pp. 5, 24, 35. The locality of Lusa was then spelt Lussay, and still earlier as Lucy Bay.

† *Ann. Report of Geol. Survey* for 1896, p. 70.

	Estimated thickness in ft.
4. *Shaly beds.* Fissile micaceous and calcareous sandstones, dark shales and earthy limestones: various species of *Arnioceras* (Semicostatus zone); *Coroniceras lyra* (Bucklandi zone); *Gryphæa arcuata* etc. .. .. .. exposed to at least	125
3. *Sandstones.* White sandstones (freestones) with rootlets in places; quartz conglomerate (with pebbles up to 2½ in. in diameter) and sandy limestones that become decalcified and weather into sandstone	25
2. *Limestones.* Dark blue limestones with occasional bands of quartz conglomerate, shaly partings and layers of sandy limestone. Ob Breakish coral bed; with "*Thecosmilia martini*," gasteropods, *Ostrea* and other lamellibranchs	65–75
1. *Sandstones and limestones.* Alternations of sandstone and limestone with some shaly beds and quartz conglomerate. Lusa coral bed in upper part, with "*Isastræa murchisoni*"; also *Cardinia* etc. ..	10–15

The conglomeratic bands that occur in the Lower Lias contain apparently no fragments of Torridon sandstone, but only quartz pebbles. A white sandstone with rootlets, observed to the east of Ardnish, is of interest, as it resembles rootlet beds found in the Lower Oolitic series (Estuarine beds) of England.

The calcareous strata at Lusa Bay, first mentioned by Macculloch, were rightly described by Murchison in 1827 as belonging to the "very lowest part" of the Lias, and he then observed the coral bed with "*Astrea*." *

Hugh Miller, in his "Cruise of the Betsey," † described not only this lower coral bed but the higher one, which contains the form since described as "*Thecosmilia*."

The Pabba Shales which form the upper portion of the Lower Lias, are divisible into four palæontological zones, as already shown.

BROADFORD DISTRICT.

The strata exhibited in descending order at Lusa, are as follows:—

			Ft.
Broadford Beds.	3	Honeycombed and pitted calcareous sandstones; the top layer containing quartz pebbles an inch or two in diameter	25
	2	Several bands of limestone with corals, and a prominent bed with "*Thecosmilia martini*" at base (Ob Breakish coral bed), underlying sill of basalt	20 to 30
		Fossiliferous limestone, with *Ostrea* and gasteropods	
		Thin sandstones and limestones	15
		Hard compact limestones, weathering like Carboniferous limestone; *Ostrea* in places	30
	1	Hard grey sandy limestone and calcareous sandstone with *Cardinia* .. .. 1 ft. 3 in. to	2
		Hard pale grey, white and yellow calcareous sandstone	5
		Lusa coral bed. Blue limestone with "*Isastræa murchisoni*," *Ostrea*, *Lima* etc.	2
		Hard grey and somewhat sandy limestone	1
		Soft micaceous sandstones and hard beds of calcareous and micaceous sandstone .. .. 4 ft. to	5

* "Supplementary Remarks on the Strata of the Oolitic Series, and the Rocks associated with them, in the counties of Sutherland and Ross, and in the Hebrides," *Trans. Geol. Soc.*, ser. ii. vol. ii. p. 362.

† See pp. 143–147.

Sir A. Geikie noted beneath the limestone, 1 ft. thick, green and yellow sandstone, 3 to 15 ft.; and at base fine conglomerate, 2 to 3 ft.*

The Lusa coral bed with *Isastræa* may be represented at Heast in the basal limestones of the Lower Lias. This coral bed was traced through Upper Breakish. It was well seen in a quarry about one-eighth of a mile west of the cross-roads, and a little north of the Kylerhea road.

From the bed below the Lusa coral bed, noted by Mr. D. Tait as "dark granular limestone," he obtained *Chemnitzia* ?, *Natica* ?, *Anomia* ?, *Mytilus* ?, *Ostrea* and *Plicatula*: identified by Dr. Kitchin. It is worthy of note that gasteropods occur also beneath the Ob Breakish coral bed, at a higher horizon.

The thickness of the Ob Breakish limestones and shales was estimated by Professor Judd at not less than 150 ft., but, as he remarked, "their thickness can be estimated only roughly." †

With a dip of about 7° and a width of outcrop of about 200 yds. at Lusa, their thickness may be about 75 ft. at that locality. Elsewhere it is not possible to obtain any measurements.

With the general succession indicated by Professor Judd, and with the thicknesses of the higher and more fossiliferous strata, our observations are in accord.

In the outlying tract of Lower Lias at Applecross in Ross-shire, oolitic structure is well developed in some of the limestones, a feature of interest in connection with the coral beds of Strath; but in this area oolitic structure is nowhere definitely exhibited.

In the scarp to the south-east of Skulamus, beds of soft sandstone with *Cardinia* (as at Lusa) and with small obscure casts of bivalves were exposed, together with intercalated layers of dark blue limestone, with quartz grains, and calcareous grit. *Ostrea* occurs in the lower layers.

The strike of the main mass of Lower Lias limestones (2) coincides practically with the trend of the coast south-west of Lusa burn, and the tidal inlet of Ob Breakish. To the south-west of the burial ground of Cill Ashik, near the north-eastern end of Lower Breakish village, the Ob Breakish coral bed is exposed; ‡ and curiously enough, here as at Lusa, it is overlain by a sill of basalt, remnants of which adhere to its weathered surfaces. The lower portion of the grey coral rock is a compact limestone, with *Ostrea* and gasteropods, as at Lusa. The weathered surface and joints of the stone exhibit lines, perhaps of fine jointing.

The ground rises to the high road at Upper Breakish, forming in fact a dip-slope that coincides generally with the limestone series, with its included layers of calcareous sandstone. These rocks are fairly free from drift and peat, and whether in the rugged reefs along the sea-margin, or over the inland slope where they jut out prominently in many places, they are remarkably weathered, some of the limestone reefs appearing like solidified wavelets. The higher coral bands may be found in many places, notably by the Cave north-west of the School. This tract of limestone ground is cultivated in narrow strips of oats, rye and potatoes.

* *Op. cit.*, p. 5.

† "The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 700.

‡ See Judd, *op. cit.*, p. 700.

In the south-western part of Lower Breakish, there are sloping pavements of limestone and calcareous sandstone, the latter quarried here and there as "freestone." The dip is in places from 6° to 8°. The limestone occasionally contains quartz pebbles, an inch or more in diameter.

The inlet of Ob Breakish separates the limestone series from the overlying sandstones of division 3.

In the promontory of Ardnish, the upward succession is continued in a series for the most part of sandstones, calcareous sandstones and shaly beds, with occasional limestones. These strata (Nos. 3 and 4) can be followed in the reefs to the north-east, where white sandstones with rootlets, and calcareous sandstone with fucoidal markings (3), are followed by (4) calcareous and shaly beds yielding species of *Coroniceras*, *Lima* (*Plagiostoma*) *gigantea*, *Gryphæa arcuata* etc. These fossiliferous beds, observed by Macculloch, were designated by him the "gryphite limestone." *

Along the north-western shores of Ardnish, the sandstones become more shaly and darker in tint. *Gryphæa* is abundant, and *Coroniceras lyra*, *Arnioceras falcaries*, *A. robustum*, and *Asteroceras* sp. are met with in the higher beds. The strata, which include micaceous sandy limestone and calcareous sandstone, are well seen in elevated reefs off Rudh' Achadh a' Chùirn, by the roadway at Sgiabain, and by the roadway as far as the mouth of the stream Allt na Cloiche Bideich at Sgiabain. The occurrence of a form near to *Asteroceras brookei* suggests that portions of the *Obtusus* zone may here be represented.

Westwards of Skulamus the Lower Lias continues as a belt along the coast, and extends southwards over the boggy highlands of Heast to an altitude of 800 ft. The rise of the ground being in excess of the dips of the strata, higher portions of the Lias would have been encountered over a larger area but for several faults which traverse the area in a N.N.W. direction. Thus the Lower Lias is repeatedly depressed on the north-east, and it is only on the highest portions of this more elevated region, on Cnoc Carnach and south of Loch na Starsaich, that tracts of the overlying Pabba Shales occur. Along the upper part of the burn Allt na Heast, south of Loch na Starsaich, the black shales are well exposed with a south-westerly dip. Here I obtained ?*Liparoceras* cf. *intracapricornum*, also *Deroceras muticum* and *Pholadomya ambigua*.

At Sgiabain the Ob Breakish coral limestones may be traced southwards from the main road, along the course of the river. The rocks at first dip to the north-west at 3°, but further south the dip becomes westerly and south-westerly, and the coral limestone occurs to the north-west of the large enclosure south of Harrabol, repeated possibly by faulting. The general strike south of Harrabol is to the south-east towards the western side of Braigh Skulamus. There the limestones are overlain by sandstones with calcareous conglomerates containing quartz pebbles; by the *Gryphæa* beds, exposed a little further south; and by sandy micaceous limestone and shaly sandstone, and dark shales, beds which are exposed along the higher course of Allt a' Choire Bhuidhe and extend westwards over peaty ground to Allt a' Choire.

* "A Description of the Western Islands of Scotland," 1819, vol. i. pp. 320, 321, 354.

Along their eastern outcrop the coral limestones and associated sandy limestones extend through the track-way to Heast, and they form the lower of a series of scarps that strike southwards across Braigh Skulamus and Glac an Skulamus—the higher scarps consisting of the sandstones (freestones) and shaly sandstones. The basal scarps include also a coral rock, probably that of Lusa, seen here and there along the lower ground to the east. A band of hard blue limestone, south-east of Braigh Skulamus, contains an altered shaly layer like that noticed in the south of Raasay. The lower beds are associated with soft sandstone.

The ground is affected by slips, and there is evidence of faulting, which could be determined by a detailed survey of the subdivisions in the Lower Lias ; but time did not permit of this.

The limestones and calcareous sandstones are well seen in the deep rocky channel of the stream south-east of Harrabol, while elsewhere the groups of weathered rocks stand out locally on the dip-slopes in jagged scarps, or in clusters like ruined cemeteries.

The calcareous sandstones show the characteristic honeycomb weathering, and when the limestones contain bands or lenticles of more sandy material, these stand out on the weathered faces of the rock. The purer limestones, while they are channelled out in irregular ways, present smoother outlines. The general aspect of the ground is like that of a Carboniferous limestone tract.

The effect of weathering on the fossiliferous shaly beds and intercalated limestones on the uplands of Heast, south of the " Chalybeate Well," is seen in beds of ochreous loam with cavities from which numerous specimens of *Gryphæa arcuata* have been removed by dissolution ; while each band of limestone has been separated into irregular weathered blocks which entirely disappear towards the outcrop. Ammonites, *Pteria*, and *Pecten textorius* were found in the beds.

In the area between Sgiabain and Broadford the strata are less continuously shown in the reefs, as they are much covered by recent marine deposits. Numerous dykes and sills of basalt, here as elsewhere, diversify the rugged foreshore.

The limestone series is developed on the eastern side of the old Pier, and the beds have been quarried along the coast between the Pier and the Corn Mill, for use in the limekiln. Reefs of hard and dense blue limestone, together with somewhat argillaceous beds and shale, appear east of the Pier, whence they dip seaward and are cut by numerous basalt dykes.

The limestones are characterised by *Ostrea*, and they contain also *Gryphæa* sparingly. They lie below calcareous sandstones which extend along the foreshore to the north, and are probably faulted on the west. These sandstones have been quarried in many spots.

The limestone is mostly concealed by a thin irregular capping of gravel east of the Corn Mill, but it appears along the course of the burn south-west of Sgiabain. The general strike corresponds with the trend of the reefs.

The *Gryphæa* beds appear to the north of Glas Eilean, the reef promontory north-west of Sgiabain, where they have a north-westerly dip. *Coroniceras* sp. occurs in the outer reefs.

A fault at Sgiabain shifts the outcrop of the main series of lime-

stones a little further north, on the western side of the dislocation, and modifies the strike.

On the western side of Broadford Bay, from Rudh' an Eireannaich southwards to the mouth of the river, there is a succession of calcareous sandstones, with occasional limestones and shaly beds with abundant specimens of *Gryphæa arcuata*. The beds have a northerly and north-westerly inclination to a little distance south of the Steamboat Pier, beyond which there is evidence of disturbance and faulting, the same beds being repeated, with a westerly dip. *Pinna, Lima* and *Rhynchonella* may be observed in some of the layers, and they all belong to the *Gryphæa* beds. Some of the bands of limestone are argillaceous and appear suitable for the manufacture of cement, as were strata on a similar horizon, south of Harrabol.

Between Broadford Bridge and the old Pier, the reefs have a general dip at high angles to the west. They consist of limestones, shales and calcareous sandstones, the sandstones predominating. The beds are evidently much faulted, but the reefs are isolated by beach accumulations.

The area west of Broadford was found to be difficult to interpret, owing to coverings of drift and peat, and partly to alteration of the Lias by contact with sills of granophyre.

North-west of Corry the junction of the calcareous sandstones and overlying Pabba Shales is by no means definite.

The mass of the shales contains harder sandy and flaggy calcareous bands with fucoidal markings and calcareous nodules. The fossils, poorly preserved, include *Amblycoceras xiphus*, *Liparoceras vesta*, *Asteroceras* aff. *brookei*, *Belemnites*, *Gryphæa* and *Pecten* in the higher beds. *Arnioceras* sp. and ? *Asteroceras redcarense* (suggestive of the *Obtusus* zone) were met with in what appeared to be the lower beds exposed. *Arietites fowleri*, ? *Amblycoceras planicosta*, *Lytoceras salebrosum* and *Pholadomya* were also obtained.

The beds have a general dip northerly, slightly to the east of north; and there would appear to be a succession upwards as we proceed along the coast towards Rudha na Sgianadin. The succession, however, is not clear, and there may be repetition by faults. The fossiliferous beds of Pabba seemed to be imperfectly represented, and are possibly in part faulted out of sight.

The highest portions of the Pabba Shales consist of dark slaty shale and paper shales with pyritous nodules, weathering red, and they are overlain by sandstones referred to the Middle Lias.

The ground at Beinn Bhuidhe is obscure, being much peat-covered, but outcrops of sandstone and micaceous shaly sandstone occur in many places, and indicate that the strata in all probability belong to the upper portion of the Broadford Beds. Pabba Shales occur to the south, and are seen by the Broadford River three-quarters of a mile west of the Church, near Broadford Bridge. Still further south, along the borders of the largest tributary of the Broadford River from the south, there are fissile shaly sandstones, sandstones and limestones which occur successively towards Suardal—and indicate lower stages to near the base of the Lower Lias.

In Camas na Sgianadin, two miles north-west of Broadford, there are beds of dark micaceous sandy shale dipping in a W.S.W. direction at angles of 10° and 50°. They are probably faulted on this western

side of the bay as well as on the eastern side. Poorly preserved ammonites occur. They appeared to belong to the lower part of the Pabba Shales, and were identified as *Echioceras macdonelli*. A fragment of *Pteria inæquivalvis*? was also found. H. B. W.

AREA SOUTH AND WEST OF THE BROADFORD DISTRICT.

The Secondary sequence in this area extends up to and possibly a little beyond the top of the Lower Lias; but its lowest members thin out and are gradually overlapped both southward and westward.

Owing to the synclinal disposition of the rocks and the south-westerly pitch of the fold, the highest part of the succession recognised (Pabba Shales) occurs only along the middle of the Jurassic tract and towards its south-western end.*

The subdivisions of the Broadford Beds, established by Mr. Woodward in the district already described, render it possible to trace the changes in these strata southward and westward from Broadford Bay. Along their eastern outcrop all these groups can be recognised southward nearly as far as Heast, the sandstone (3) above the limestones (2) making a bold feature, for some distance just above the road and always near it, while the limestones produce tiers of escarpments below. Except that before reaching Heast the lower two groups, respectively of sandstones with limestones (1) and of limestones (2), become inseparable, Mr. Barrow found the same lithological subdivisions still well marked at Heast and Boreraig. The limestones and the overlying white sandstones (3), persistent as far as the coast, are succeeded by the highest group (4) of the Broadford Beds, there comprising in ascending order thin *Gryphæa* limestones followed in turn by soft shaly strata with numerous bands of *Gryphæa arcuata* and upper calcareous sandstones.

Inconstant conglomeratic beds of quartz pebbles in a calcareous and sandy matrix develop frequently in the lowest part of the Lias, and are not always easy to distinguish from the Triassic conglomerates, where the variagated marl and the Passage-beds are not exposed. Mr. Barrow, taking a compact buff limestone as the base of the Liassic limestones, states that near Boreraig it changes laterally into conglomerates of quartz and sometimes of limestone (see Chap. IX.). These develop upward at the expense of the lower limestones both before and after the Trias has died out laterally.

Southward along the western outcrop, also, the lowest subdivision of sandstones and limestones (1) first becomes unrecognisable, but the others all persist as far as the head of Glen Boreraig, beyond which the sandstone (3) above the limestones (2) was not found. Where the Trias thins away not far from the coast, the limestone subdivision of the Broadford Beds has also diminished, and does not extend as far as Loch Slàpin. For near the mouth of Allt Lèth Slighe the lowest beds of the Lias consist of 25 ft. of dark blue indurated muddy ammonite-bearing limestones of a different aspect, with thin partings of black sandy shale and *Gryphæa arcuata* bands throughout, down to the basal bed welded on to the Cambrian limestone. The inclusion of Durness chert and limestone pebbles shows that, like the neighbouring

* (Sir) A. Geikie, "On the Geology of Strath, Skye," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. p. 6.

calcareous Trias, they derived much material from the underlying Palæozoic limestone.

The local base of the Lias here belongs to the highest subdivision (4) of the Broadford Beds. The rest of this group, roughly about 175 ft. thick, as seen in the fine cliffs of Loch Slapin and inland in Glen Boreraig, consists of earthy sandstones and sandy shales in the lower part, but principally of sandstones with thin beds of shale and rare limestone bands in the upper. The sandstones, blue and calcareous when fresh, but usually of a brownish earthy appearance at the surface, perhaps bulk more largely here than in the Broadford district. Where indurated in the neighbourhood of the granite mass of Beinn an Dubhaich, they take on a dark greenish hue, but are comparatively unaltered south of the gabbro intrusion of Glen Boreraig. On the south side of this valley they pass under the Pabba Shales, which monopolise the cliffs and shore for the next two miles.

On Loch Eishort the highest sandstone of the Broadford Beds, after reappearing for a short distance below the cliffs of Creag an Daraich east of Càrn Dearg, is then faulted down below sea-level, but rises again at the old fort west of Boreraig, whence it strikes inland above a sill traversed by small faults. Eastward the whole descending sequence crops out down to the limestones at Boreraig. Mr. Barrow finds the sandstone (3) above the lower limestones making a bold feature on the hillside below the mass of granophyre between Boreraig and Heast.

The sedimentary rocks are somewhat indurated in the neighbourhood of intrusive masses, but even near the granite of Beinn an Dubhaich and Beinn a' Chàirn metamorphism is not so intense as to preclude the determination of characteristic organisms.

Palæontologically three broad divisions present themselves in the Lower Lias of the southern part of Strath. The first comprises the Broadford Beds, except their highest subdivision, and is apparently devoid of cephalopods and gryphæas, while the second and third, consisting respectively of the upper Broadford Beds and the lower Pabba Shales, are sharply distinguished from one another by generic and specific changes in those fossils.

On Loch Eishort, at the waterfall halfway between Tôrr Môr and Boreraig, about 100 yds. west of the highest limestones, the shaly beds with *Gryphœa arcuata* yielded numerous specimens of *Arnioceras*, including *A. bodleyi* and *A. hartmanni*, as determined by Mr. S. S. Buckman. Below this horizon there is room for some development of the *Bucklandi* zone. On Loch Slapin, however, the abundance of ammonites belonging to species of *Arnioceras* in the thin basal limestones lends colour to the supposition that the true *Bucklandi* beds may there have disappeared completely in the overlap of the *Semicostatus* zone on to the pre-Mesozoic uplift of the Cambrian limestone. But still *Arnioceras*, which continues to occur up to the top of the Broadford Beds at the mouth of Glen Boreraig on Loch Slapin, is associated in the upper part of this thickness of shales and calcareous sandstones with occasional specimens of *Agassiceras spinaries* and ? *Coroniceras aussoniense*. Hence it appears that, while the whole thickness of these beds on Loch Slapin may reasonably be assigned to the *Semicostatus* zone, no rigid differentiation of the *Semicostatus* and *Bucklandi* zones is there possible.

On Loch Eishort the *Semicostatus* beds extend westward as far as the

sandstone overlying the dolerite sill at the ancient fort. The same sandstone, where brought up again by a fault 600 yds. further west, is overlain on the shore by a few feet of hard sandy and micaceous shales containing *Asteroceras brookei*, *A.* aff. *smithi*, *A. stellare* ?, *A.* cf. *suevicum*, ? *Arietites impendens*, and *Amblycoceras* aff. *planicosta*. These sandy shales then show a small but definite development of the *Obtusus* zone, the fauna of which was not recognised on Loch Slapin. The *Raricostatus* zone of the Pabba Shales immediately succeeds.

The absence of all evidence of the *Oxynotus* zone, a fact noted by Professor Judd,* is striking, and it is equally striking that at the horizon at which it should occur, *i.e.* between the Broadford Beds and the Pabba Shales, an abrupt change takes place in the ammonite fauna, all the characteristic forms of the lower zones giving place rather suddenly to *Echioceras* and *Deroceras* of the Pabba Shales.

A poorly preserved specimen resembling "*Microceras*" *subplanicosta*, from the middle of the *Semicostatus* beds halfway between the outfalls of Allt Lèth Slighe and Allt a Ghairbheid, and a single individual of *Arnioceras* met with just above the line taken as the base of the Pabba Shales, afford the sole examples of ammonites found to transgress this line.

The cliffs of Loch Slapin and Loch Eishort display the lower half of the Pabba Shales in unbroken sequence, but the upper only occurs inland with scanty exposures. Here Mr. Barrow finds the highest beds on Beinn Bhuidhe, where he believes that certain sandy strata possibly belong to the Middle Lias, but obtained no distinctive fossils.

The Pabba Shales in the south of Strath, where Mr. Barrow estimates their thickness at fully 700 ft., may be grouped as follows :—

Pabba Shales.

	Sandy beds (Beinn Bhuidhe).
? *Jamesoni* zone	Thick grey sandy micaceous shale.
Armatus and *Raricostatus* zones	Grey and whitish calcareous and argillaceous sandstone: *Deroceras armatum* or closely allied forms in lower half.
	Grey sandy micaceous shale with calcareous concretions and small black nodules: *Deroceras armatum*, *D.* aff. *muticum*, *Echioceras macdonelli*, *E. nodotianum*, *E. raricostatum*, *Gryphæa cymbium*.
	Soft grey micaceous shale with calcareous concretions and small black nodules: *Echioceras raricostatum*.

We have palæontological evidence for correlation only up to the middle of the calcareous sandstone. The soft shale at the base certainly belongs to the *Raricostatus* zone. The thick sandy shale may be regarded as belonging either to the *Raricostatus* or to the *Armatus* zone: *Deroceras* occurs commonly throughout, while *Echioceras macdonelli* and *E. nodotianum* were met with only in this sandy shale on the south coast of Strath. Of the calcareous sandstone the lower half alone is exposed in the cliffs, and must be assigned to the *Armatus* zone. The *Jamesoni* zone, probably represented inland by the overlying shales, and perhaps by the upper part of the calcareous sandstone, has not been identified by fossils of zonal value. *Gryphæa cymbium* replaces *G. arcuata* of the Broadford Beds, but in much less abundance.

* "The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 703.

At Glen Boreraig the northern outcrop of the Pabba Shales on the coast of Loch Slapin shows soft shale, perhaps 50 ft. in thickness, succeeding the sandy strata of the Broadford Beds, and dipping beneath harder sandy shale in the south cliff.

Southward the sandy shale forms the cliff and shore-reefs for about half a mile. Near its base *Echioceras* was found in association with *Deroceras armatum*, *D.* aff. *muticum* and "*Microceras*" *subplanicosta*.

The succeeding calcareous sandstone occupies the cliff and shore as far as Rudha Suisnish, whence, as the dip veers round, it rises and crops out at the top of the cliff about 200 yds. east of that promontory. *Deroceras* of various species, plentiful in the lower part, is found throughout in the cliff section, which however does not embrace the highest beds.

At Rudha Suisnish the top of the sandy shale, here containing ? *Echioceras tardicrescens*, emerges on the shore and gradually replaces the sandstone in the cliff eastward.

Not far west of the gabbro cliff below Càrn Dearg the lower soft shale reappears, with *Echioceras raricostatum* prominent amongst allied forms. Coincidence of coast-line with strike mainly accounts for its persistence on or just above the shore for more than half a mile beyond this gabbro ; but the faulting of the margin of the granophyre above suggests the eastward repetition of ascending strata by small easterly downthrows. One of these seems to bring the higher sandstone down again into the top of the lofty cliff below the east end of the granophyre, and 150 yds. east of the waterfall.

The Pabba Shales, passing under this granophyre, have been traced inland by Mr. Barrow around it and Beinn Bhuidhe to Glen Boreraig.

C. B. W.

SRATH BEAG.

A tract of Lower Lias * lies around the south end of Srath Beag, where it is much obscured by drift. It reaches an altitude of about 1000 ft. on the flank of Beinn Dearg Mhòr.

The Pabba Shales, which evidently occupy most of this tract, for the lower beds dip steeply southward, have not been mapped out, owing to the poverty of palæontological and other evidence.

Along the northern margin the lowest beds of the Lias, blue limestones, sometimes baked to white marble, and calcareous sandstones, show a thickness of about 45 ft. Bent up sharply against the granophyre in Srath Beag, they ascend the western slope of Beinn Dearg Mhòr, where the granophyre and the agglomerate at first transgress rapidly from lower to higher beds of the Lias along its eastern boundary.

For a short distance southward from these limestones in Allt an t-Sratha Bhig, the succeeding indurated micaceous shales, with south-westerly dip, must belong to the highest subdivision (4) of the Broadford Beds, though no sandstone was observed. About 370 yds. south of the granophyre, poorly preserved ammonites (*Echioceras* ?) in micaceous shale suggest that the sequence has already reached the Pabba Shales ; while similar shale 100 yds. further south, with

* (Sir) A. Geikie, "On the Geology of Strath, Skye," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. p. 6.

ammonites doubtfully identified as *Echioceras* sp., *E. raricostatum*, *Deroceras muticum*, and "*Microceras*" *subplanicosta*, must certainly be assigned to the lower part of that division. Grey calcareous and micaceous sandstones follow, and the upward sequence consists further of shales and sandstones as far as the westward bend of the stream, about 200 yds. north of which point specimens of *Echioceras raricostatum* ? were again found.

The higher course of Allt Slapin, below the agglomerate, shows indurated sandstones, probably those noted in Allt an t-Sratha Bhig. These are succeeded lower down the stream towards Cnoc Slapin by micaceous Pabba Shales, dipping south-west, with numerous ill-preserved fossils, including *Lima antiquata*. Shales, probably the same, exposed in Allt an t-Sratha Bhig below its westerly bend, contain beds of sandstone and abundant *Gryphæa* of the broad *cymbium* type.

Streams descending from Clach Oscar show similar indurated shales with sandstones, and near the bridge at the mouth of Abhuinn an t-Sratha Mhòir red-stained sandstones are seen. As the Inferior Oolite crops out beyond the alluvial flat, the upward sequence may possibly reach the Middle Lias in these stained and metamorphosed sandstones.

A narrow strip of indurated Lower Lias sandstone and shale is faulted in along the shore south of the school at Torran.

South of Allt Slapin the Lias, ending suddenly against granophyre and Durness limestone, is probably cut off by a fault. Its junction with the Durness limestone of Cnoc Slapin is also a fault, seen to have a reversed throw in Allt an t-Sratha Bhig, where that limestone slightly overhangs the Lias.

STRATHAIRD.

The Mesozoic strata of Strathaird, since Macculloch recognised them as such, have received little or no attention from geologists, except an occasional brief reference by Professor Judd.* The recent survey of the ground, however, has not borne out the conclusions arrived at by the latter, so far as they are indicated by his sketch-map and his few allusions to that district. On Sir A. Geikie's Geological Map of Scotland, the sedimentary rocks of Strathaird are all coloured as of Oolitic age.

Blath-bheinn.

On the west side of Strathaird the Camasunary fault brings up a mass of Lower Lias, for the most part greatly metamorphosed. †

Where the footpath crosses Abhuinn nan Leac below the upper waterfall, the exposure of Torridon Sandstone in the stream comes to an end. On the north side of the ford, altered blue limestone in a small bluff passes northward under calcareous sandstones and shales with *Gryphæa* beds in the stream. Here the lowest part of the Lias is thrown down against Torridon Sandstone by a north-westerly fault.

Above the most southerly patch of basalt on the south spur of the Blath-bheinn range, a faulted cliff-face gives a more complete section of these beds. Thin white indurated sandstone with quartz

* *Op. cit.*, pp. 667 etc., 714, and 722; also map, plate xxxi.
† *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 143.

pebbles, resting on Torridon Sandstone on the west, is succeeded by a group of metamorphosed blue limestones with thin shales and several basic sills, the whole of considerably greater thickness than the basal limestone on the shore of Loch Slapin, though perhaps not thicker than the limestone group on Loch Sligachan. Altered shales and dark impure sandstones follow the calcareous beds in the eastern part of the section. The pebbly sandstone, separated from the limestones by 6 ft. of shale, probably denotes a conglomeratic base of the Lias, as near the shore of Loch Eishort, rather than a representative of the Trias.

At the north end of the Liassic tract on the west side of this mountain ridge the lowest bed seen in the Jurassic sequence is a metamorphosed blue limestone, of a nodular or conglomeratic appearance, between two tongues of granophyre,* the lower of which may cut out the actual base. Higher beds seem to contain gryphæas. Sandstone comes on above, and the rest of the succession as seen consists chiefly of altered sandy and shaly strata. In the upper part a thin-bedded blue crystalline limestone, 8 or 10 ft. thick, overlies a white calcareous sandstone with doggers and passes below similar altered sandstone with doggers, the highest beds visible. The thickness of Lias exposed on this side of the ridge may be no more than 300 ft. Some distance from the top *Arnioceras* cf. *geometricum* was recognised in the sandstone by occasional moulds.

On tracing the ascending sequence up Abhuinn nan Leac from the sandy *Gryphæa* beds overlying the limestones, we find chiefly indurated shales with *Pecten*, *Rhynchonella* and other shells, inclined slightly but irregularly, and repeated by two upthrow faults, between which, 600 yds. north of the waterfall, ammonites doubtfully referable to *Echioceras* were found. Beyond these faults the strata have a general south-easterly inclination away from the strip of underlying granophyre, off which limestones crowded with *Gryphæa* dip south-eastward under shales and sandstones with *Gryphæa* and ammonites referred with some hesitation to *Arnioceras*. The same beds continue with south-easterly dip up the eastern flank of the mountain, above the granophyre ; but finally bend over anticlinally and pass north-westward under the gabbro. The highest strata show a sequence similar to that on the west side of the ridge, a thin-bedded blue limestone intervening between white sandstones with doggers, the upper of which dips under the gabbro.

Thus it seems that no greater thickness of Lower Lias obtains on the east than on the west side of Blath-bheinn, though the Lias rises to a greater altitude on the east, for the approximate coincidence of dip and slope on the lower flank carries the basement beds higher than on the west. The upward succession in Abhuinn nan Leac doubtless reaches the Pabba Shales in the shaly strata above the sandy *Gryphæa* beds south of the cross faults. But the *Gryphæa* limestones in the upper part of the stream have the same relation to the granophyre that the basal beds have elsewhere in the neighbourhood, and may be expected to belong to the lower part of the *Semicostatus* zone. The beds underlying the gabbro of the mountain spur may be Pabba Shales.

A short distance east of Abhuinn Camas Fhionnairidh, near its mouth, a little patch consists of blue limestone with shaly partings, resting

* The upper is not shown on the one-inch map.

on hard greenish sandstone and underlying shaly and shelly sandstone. The whole, merely a few feet thick, is intercalated between Torridonian strata and Tertiary basalts. It evidently represents the base of the Liassic series, perhaps with an equivalent of the Passage-beds.

LOCH SLIGACHAN DISTRICT.

The lowest group of the Lias consists of marine blue shelly limestones, often indurated and coarsely crystalline, with intercalated dark shales. Towards the top the shales increase in frequency and thickness, and the limestones contain numerous bands of *Gryphæa arcuata*. The presence of a bed of ill-preserved corals ("*Thecosmilia*" ?) below the highest limestones, as in Strath, and the absence of the characteristic fauna, especially the ammonites, of the overlying shaly beds, are sufficient to assign the lower and greater part of these limestones to the limestone subdivision (2) of the Broadford Beds. For the sandstone (3) above this subdivision in the north of Strath has not been recognised. The lowest group (1) of that district, if present here, seems inseparable from the limestones. As the highest limestones contain numerous *Gryphæa* bands and more shale, they may be regarded as homotaxial with the lower part of the shaly and calcareous beds of the highest Broadford subdivision (4). The limestone group of Loch Sligachan seems then to represent the Broadford Beds from the base of that subdivision downwards, with a probable diminution of thickness, but without loss of conformability to the Passage-beds which, with the Trias, remain constant.

Similarity of character, the scantiness of fossil-evidence, where the rocks are much indurated, and the prevalence of faults, render the remainder of the sequence difficult to follow in detail. Hence we have not attempted to map out the Pabba Shales. The general succession is :—

Pabba Shales (*Arnatus* and *Raricostatus* zones)	Thick grey fossiliferous, micaceous and more or less sandy shales : *Echioceras macdonelli* and in lower part *E. edmundi* occasionally found : *Gryphæa cymbium*.
Broadford Beds (*Semicostatus* and *Bucklandi*? zones)	Calcareous shaly sandstones and shales with *Gryphæa arcuata*.
	A smaller thickness of shales with beds full of *Gryphæa arcuata* and *Pteria* (*Oxytoma*) *inæquivalvis* ; *Arnioceras geometricum* ?.

No actual evidence of the *Bucklandi* zone was found, and the scanty testimony of the few ammonites obtained suggests no room above the *Gryphæa* limestones for the development of a *Bucklandi* fauna unmixed with ammonites of the *Semicostatus* zone.

East of the large northerly fault the lower courses of the burns best display the sequence, for drift obscures the surface. Dark shaly sandstones, some little distance above the limestones, appear to have considerable thickness. In the two burns nearest the new school on the east, and in another immediately west of it, dark micaceous and more or less sandy Pabba Shales are exposed with general north-westerly dip at high angles. In the burn next to the school on the east, 300 yds. south of the road, *i.e.* below the middle of the thickness seen, the shales contained *Echioceras macdonelli*. Similar shales in the immediate neighbourhood yielded belemnites, *Lima antiquata*, *Hippopodium*,

Nuculana tatei, *Pecten* and *Unicardium cardioides*. The sandstone of the *Armatus* zone in southern Strath was not seen here.

West of the northerly fault a group of calcareous earthy sandstones and shales comes on not far north of and above the limestones. One of its higher sandstones makes an escarpment west of the school, and the top of this rock descends in a steep slope to the margin of the loch, where *Echioceras edmundi* occurred in the overlying shales, presumably the base of the Pabba Shales (*Raricostatus* zone). The sandy group below must belong in the main to the *Semicostatus* zone. In view of the paucity of ammonites, it is not surprising that the *Obtusus* beds of Loch Eishort were not found here.

North-westerly faults throw up lower beds on the west. One of these faults brings the limestones down the slope to the road nearly 600 yds. W.S.W. of the school. Shales immediately above contain masses of *Pteria* (*Oxytoma*) *inæquivalvis*, besides *Gryphæa* bands, while the same beds in a burn about 600 yds. further west yielded *Arnioceras geometricum*?. Doubtful specimens of *Arnioceras* were obtained also at a rather higher horizon in the next burn westward. The lower strata of the overlying sandy group run down to the shore, whence that group strikes obliquely up the slope and makes a series of distinct escarpments not far from the limestones. It dips north-westward under dark micaceous Pabba Shales, seen in all the burns that descend the lower slope and passing under the strip of basalt on the coast. The highest shales afforded numerous badly preserved fossils, but no determinable ammonites. "*Chemnitzia*" *trivia*, *Cardita multicostata*, *Lima pectinoides*, *Pecten æquivalvis* and *Spiriferina pinguis* have been recognised somewhat doubtfully. Neither lithological character nor palæontological evidence suggests that the succession has reached the Middle Lias, but it has probably reached here a high horizon of the Pabba Shales.

From Leathad Dubh eastward the whole descending sequence, bent over anticlinally (see Fig. 4), passes under the basalt escarpment, the limestones, often much altered, being seen at intervals almost up to it. Eas Mòr, falling over the outer ledge of the igneous rocks in a cascade, has cut a gorge in the Torridon Sandstone through the Mesozoic basement beds, and breaks the symmetry of their anticlinal outcrops.

The northerly fault further east throws down on the east dark micaceous fossiliferous shales of the Pabba series, still dipping southward under the basalt. This fault, and another which almost joins it on the west, enclose between them a little patch of metamorphosed Liassic limestone with white pebbly sandstone below, resting upon Torridonian close to the margin of the basalt.

Further east on lower ground due south of Sconser Lodge, the Liassic limestones and *Gryphæa* beds dip southward off the Trias under indurated shales. These latter quickly bend up again and dip at a high angle northward from beneath the basalt, the limestones also just appearing here and there. C. B. W.

ISLAND OF PABBA.

The Island of Pabba, or Pabay, is formed mainly of dark sandy and micaceous shales with hard calcareous and slightly ferruginous nodules which weather red.

The strike of the strata corresponds generally with that in Ardnish in Skye.

The lower beds of micaceous sandy shale and fissile and calcareous shaly sandstone—with a dip of 5° to W. 15° N.—are seen on the south-eastern coast. They represent the *Armatus* zone. Here fossils are not so abundant as in the higher strata belonging to the zone of *Uptonia jamesoni*, that are well exposed in the low cliffs and reefs on the north-western and north-eastern shores. The *Obtusus* zone, which may be represented to some extent on the Ardnish shore, and perhaps the *Oxynotus* and *Raricostatus* zones, are concealed by the sea between Ardnish and Pabba. No specimens of *Oxynotoceras oxynotum* have been recorded from Skye or adjacent islands (see p. 106).

The preservation of the island of Pabba is largely due to the bulwark of dykes and sills by which the ravages of the sea are in general hindered. In some instances, however, there are reefs which in very stormy weather are said to aid destruction by increasing the force of the breakers.

Many fossils were collected by Murchison in 1826 : they included *Ammonites brevispina* J. de C. Sow., the original type specimen, and also *Gryphæa maccullochi* J. de C. Sow. then figured as new,* but now recognised as synonymous with *G. cymbium* Lam.

Hugh Miller described, in enthusiastic language, Pabba and its fossil treasures.†

Other fossils from Pabba are recorded by Wright ‡ and by R. Tate. §

SCALPA.

Since the mass of Middle Lias was mapped, Mr. Harker has found a considerable area of dark shales, with an occasional band of sandstone, to the south-west of the Middle Lias ; and these strata, from their position and inclination, belong in all probability to the Pabba Shales.

RAASAY.

The Lower Lias can be examined in scarps, low cliffs and ledges west of Rudha na Cloiche, and at Suisnish by the "Narrows" of Raasay. There we find a striking resemblance between some of the layers of hard blue limestone, of *Ostrea* beds and *Gryphæa* beds, and equivalent strata in Somerset ; and it was interesting to read that Macculloch, in 1819, remarked that the fossils "resemble generally those found in the lias of Somerset and Gloucestershire." ||

This lower division, comprising limestones, shales and calcareous sandstones, belongs to the Broadford Beds so well exposed on the coast at Broadford ; and it is surmounted by dark shales with ferruginous nodules (Pabba Shales) well seen at Pabba. The shales are more micaceous than those in England, but in general

* *Trans. Geol. Soc.*, ser. ii. vol. ii. p. 322.

† See "Cruise of the Betsey," pp. 149 etc.

‡ "Notes on the Fossils collected by Mr. Geikie from the Lias of Pabba, Scalpa and Skye," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. p. 26.

§ "On the Palæontology of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. p. 342.

|| "A Description of the Western Islands of Scotland," 1819, vol. i. p. 251.

characters the strata called to mind the *Raricostatus*, *Armatus* and *Jamesoni* zones, and many of the same fossils were to be found.*

In this southern end of Raasay the beds are not continuously exposed. The old scarps are masked by boulder clay and peat, and much overgrown in places with vegetation; moreover, the continuity of the Lias is broken and shifted by faults, and hidden beneath a sheet of granophyre.

The Lower Lias limestones have been worked for lime-burning at the kiln south of Suisnish; there the limestone is hard and splintery and sharply broken up by rhomboidal joints, the faces of which sometimes show polished greenish coatings. The intervening shales that there contain *Ostrea* are indurated almost into a kind of lydian stone, and resemble the altered Lias of Portrush. There is evidence, thus, of the metamorphic influence of the Tertiary volcanic rocks. The limestones are shown at one point on the foreshore west of Rudha na Cloiche, dipping 22° to W. 15° N.

It is not possible at Suisnish to follow up the various strata of the Lower Lias in detail, but on the foreshore near Inverarish (in Sheet 81) we find higher beds of sandy limestone, and of flaggy and shaly limestone with crushed *Pholadomya*. These beds dip about 10° to N. 7° W., and occur on the border-line between the Broadford Beds and Pabba Shales.

At Suisnish, to the south, in the overlying micaceous shaly beds with hard nodules, Tate records the following fossils :—†

Belemnites elegans.	Ostrea.
Cardinia attenuata.	Pinna folium.
Gryphæa obliquata.	

The shales are exposed in the cliff beneath an irregular mass of granophyre, and the dip is westwards. On the foreshore there are many basalt dykes which stand out like walls, and the shales are jointed and exhibit in places a rude cleavage.

Middle Lias.

BROADFORD DISTRICT.

Beds probably belonging to the lower portion of the Middle Lias occur at Rudha na Sgianadin, faulted on the west and south against Lower Lias. The beds comprise hard white and greenish sandstone, more or less calcareous and fucoidal. The dip is northerly, 8° to 12°. No fossils were, however, obtained from these strata. H. B. W.

STRATHAIRD.

The top of the Middle Lias (*Spinatus* zone) emerges at two places on the east coast. Immediately south of the raised beach at Faoilean, crags of grey calcareous and micaceous sandstone with doggers appear

* Full particulars of the Lias of Raasay were published by Dr. J. Bryce and Prof. Ralph Tate, *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. p. 317.

† *Op. cit.*, vol. xxix. p. 342. See also Judd, *op. cit.*, 1878, vol. xxxiv. p. 713.

below the road at the foot of the slope. Rising northward into the hillside above the old beach, the rock is scarcely exposed before descending again beneath the surface of the loch. Southward it was traced along the shore nearly as far as Rudha Cruaidhlinn, where it disappears below sea-level. Belemnites, *Pteria cygnipes*, *P. inæquivalvis*, *Pecten liasianus* and abundant *Rhynchonella tetrahedra* are characteristic fossils.

Some distance north of Dùn Liath, similar sandstone with calcareous doggers and beds of sandy limestone continues southward for about 600 yds. in a low bank below the outcrop of the Inferior Oolite and in reefs upon the shore. *Amaltheus turgidus*, ?*Paltopleuroceras pseudospinatum*, *Pteria inæquivalvis* (abundant), *Pecten æquivalvis*, *P. liasianus* and *Rhynchonella acuta* (abundant) occurred amongst other species. C. B. W.

SCALPA.

On the south-eastern side of Scalpa there is a tract of Middle Lias, the lowest portion of which is probably not far removed from the uppermost Pabba Shales (zone of *Liparoceras capricornus*). The highest beds of the Middle Lias are probably those along the north-western portion of the area. No trace of Upper Lias was found.

While the dip is generally in a westerly direction towards the high ground of Scalpa, yet it is subject to local modification. Adjoining the Torridonian rocks along the deep and rocky course of Allt Bride, the Middle Lias sandstones are seen to dip towards the south-east, and they are much shattered. Without doubt the Middle Lias is here faulted against the Torridonian rocks on the north-west, and the continuation of this boundary to the south-west may also be a line of fault.* It would perhaps be a continuation of the faulted area at Camas na Sgianadin.

The fault at Scalpa was represented, somewhat diagrammatically, by Professor Judd.†

The Middle Lias comprises micaceous shaly sandstone and sandy shale, and micaceous flaggy and calcareous sandstone.

A few fossils were obtained from the reefs south-east of Scalpa House. They were *Belemnites*, *Gryphæa cymbium*, *Pecten æquivalvis*, *Plicatula spinosa*, *Pholadomya* and *Serpula*. Macculloch noted the abundance of the large *Pecten*.

Professor Judd, assisted by Mr. A. Grant who had resided for some time in the island, obtained a number of species, including the following :— ‡

Ammonites spinatus, *Brug.*	Rhynchonella tetrahedra, *Sow.*
„ margaritatus, *Mont.*	Terebratula punctata, *Sow.*
Rhynchonella acuta, *Sow.*	

Sandstone has been quarried on the reefs east of Scalpa House. H. B. W.

* Reprinted in part from the *Annual Report of the Geological Survey* for 1896, p. 71.
† *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 673.
‡ *Op. cit.*, p. 714.

Upper Lias.

STRATHAIRD.

Where the Middle Lias rises sufficiently to make a feature, a narrow flat or depression marks the outcrop of the Upper Lias shale below the escarpment of the Inferior Oolite. The actual contact of Middle and Upper Lias was not exposed; in fact, the lower part of the latter was nowhere seen.

Above the raised beach at Faoilean the Upper Lias is arched into the flank of Druim an Fhuarain, but soon descends southward to the road. On the slope above the pool in the beach, a watercourse exposes beds of this formation—black shale with lenticles of blue limestone, both containing abundant *Dactylioceras commune*, *D. braunianum*, *D. holandrei*, *Harpoceras falciferum* and *H. mulgravium*, not far below the base of the Inferior Oolite. The Upper Lias probably does not much exceed 20 ft. in thickness. The beds here visible lie apparently at the junction of the *Communis* and *Serpentinus* zones.

North of Dùn Liath the top of the Upper Lias, first noticed there by Mr. D. Tait, is just exposed in the foot of the cliff, but the rest is covered by the beach :—

Section at Mouth of Burn, South of Allt Mòr and North of Dùn Liath.

		Thickness. Ft.	In.
Inferior Oolite series.	Dark grey thin current-bedded coarse calcareous grits	—	
Upper Lias (*Communis* zone).	Dark blue oolitic and ferruginous limestone*	1	9
	Black calcareous shale with thin nodular bands of oolitic and ferruginous limestone in upper part.. .. .. seen for	1	1

Shale and oolitic limestone both abound in *Dactylioceras commune*, *D. angulatum*, *Belemnites breviformis* and another species. Near the top of the shale is a thin bed crowded with belemnites. The great abundance of *Dactylioceras* and the apparent absence of falcate ammonites are noteworthy in these highest beds. The junction with the Inferior Oolite is sharply defined, the gritty material coming in abruptly, so that a knife-blade could separate the two lithological divisions. The proximity of the Middle Lias shows the thickness of the Upper to be much the same as at Faoilean.

The *Serpentinus* and *Communis* zones are certainly represented in Strathaird, the latter zone extending upwards to the top of the formation.

Inferior Oolite Series.

STRATHAIRD.

A thick mass of calcareous sandstones, conformable to the Upper Lias and the Great Estuarine series, forms the eastern ledge of the

* Bryce noted oolitic limestone in the Upper Lias of Portree Harbour ("On the Jurassic Rocks of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. p. 322); and Mr. Woodward has described an oolitic ironstone at the top of the Middle Lias of Raasay ("On a Bed of Oolitic Iron-ore in the Lias of Raasay," *Geol. Mag.*, 1893, Dec. iii. vol. x. p. 493).

promontory, extends into the low ground at the north end of it, and rises westward in the flank of Sgùrr nan Each. It comprises a descending sequence as follows :—

	Thickness Ft.
III. Hard white and light grey granular sandstone, more or less calcareous, with few seams of quartz pebbles, rootlets and other plant remains	35–45
passes down through :—	
II. Dark grey shaly micaceous flags, into :— Black shale with pyritous nodules and ammonites (*Garantiana garantiana* or allied forms)	about 30
I. Calcareous, massive, and flaggy or current-bedded sandstones and grits; white, light grey or yellow at the surface, blue when unweathered: more massive sandstones predominate in the upper half, but frequently alternate in the lower with current-bedded and flaggy bluish gritty limestones or calcareous grits, which constitute the bulk of the lowest beds, and contain rarely seams of small pebbles: calcareous doggers are numerous. Marine fossils, including belemnites, occur in the lowest part and at other horizons: thickness probably not less than ..	700

The lowest group (I.) forms the outer ledge of Strathaird, a broad moorland plateau in the south, contracting northward and rising into the ridge of Druim an Fhuarain, which ascends abruptly from sea-level in numerous escarpments. Above the overlying shale bed, eroded into a small valley, the upper sandstone makes everywhere a bold escarpment.*

The bulk of the thick lower group yielded no organisms, though a few marine fossils, but no ammonites, were found at three or four horizons, the highest not far from the top. Thus we have no evidence, beyond an apparent continuity of conditions, that the whole was laid down in sea-water.

The lowest beds along the east coast contain belemnites (*B. confertus* ? and others), also brachiopods and lamellibranchs, chiefly fragmentary, but including young oysters, *Astarte* and *Pecten*. Worm-casts were noted on the surface of sandy beds near the bottom and at the top of the group; while at a horizon not far below the top of it, a bed was found containing *Lima* sp., *Pecten articulatus*, *Placunopsis jurensis* and *Terebratula* sp., the last named in abundance.

Rootlets and other plant remains contained in it do not suggest a marine origin for the highest sandstone.

Apart from the ammonites of the shale bed, which should assign that horizon to the lower part of the *Parkinsoni* zone, internal evidence of the age of the series is scanty in Strathaird. External evidence, while merely limiting its upward range by the intervention of some 400 ft. of the Great Estuarine series below the Oxfordian, more closely fixes the age of its base by the underlying *Communis* beds. Since the Upper Lias shales afford no suggestion of a *Jurensis* zone, this, as well as the *Opalinus*, *Murchisonæ* and *Humphriesianus* zones, may be included in the thick lower sandstone group (I.) of the Inferior Oolite series. But we have no indication that any but the lower part of the *Parkinsoni* zone is represented, at least by

* The road from Kilmarie southward, not constructed at the time when the one-inch Ordnance map was made, runs for a long distance at the foot of this escarpment: the track shown on the map is a footpath along the top of it.

marine strata. Nor has this zone been recognised elsewhere in the Western Highlands.*

We have grouped the white sandstone overlying the shale bed with the Inferior Oolite on the grounds of its similarity to the sandstones of that series, its downward passage into the shale, and the impossibility of separating it from the other Inferior Oolite sandstones, where the strata are altered and incompletely exposed, as immediately north of Strathaird. And Professor Judd has included in the corresponding series elsewhere beds apparently not of marine origin.† In fact the presence in the ammonite-bearing shales of a different fauna at Elgol, and of fish scales comparable with those of the lower estuarine shales of Eigg,‡ suggests a possible vacillation between marine and estuarine conditions in the highest beds of the Inferior Oolite series.

This series in Strathaird is much thicker than Professor Judd's estimate for Raasay and other parts of Skye, and more arenaceous.§ It is possible, too, that we have taken the upper limit at a lower level, for the beds immediately succeeding the highest white sandstone belong to a well-defined series of estuarine strata.

From the south point of the promontory, low seacliffs display almost the whole series in upward succession to the north-west. The lowest beds seen near the base at Rudha na h-Easgainne and on the neighbouring islet are the blue calcareous and gritty flags, passing up with a slight north-westerly dip into less calcareous thin-bedded sandstones, weathering white. From Port an Luig Mhòir they merge into less flaggy and current-bedded rocks, as more massive white and grey sandstones come on above. A thick dolerite sill succeeds beneath the overlying shale. At Port na Cullaidh the latter reaches the shore, and passes up through grey micaceous flags into a cliff of current-bedded white calcareous sandstone with some pebbly seams.

On the east coast, above a foreshore strewn with fallen blocks, steep cliffs of varying height truncate a grassy slope rising with tiers of small escarpments, and break into gullies and caves by the decay of innumerable dykes, with outstanding buttresses now and then carved into fantastic arches. Here and there, but chiefly north of Kilmarie, the bare crags give place to high green banks, dotted with stunted trees.

In the cliffs of the east coast, blue calcareous and gritty flags and thin current-bedded calcareous sandstones alternate with more massive beds of similar sandstone, the whole weathering white or yellow. Large doggers occur, and sometimes seams of small pebbles.

North of Dùn Liath the basement beds in the sheer cliff continue almost unchanged down to their junction with the Upper Lias, but become darker close to it.

On the flank of Druim an Fhuarain above the raised beach the lowest beds are of the ordinary type, but contain little angular fragments and shaly streaks just above the Upper Lias shale. Immedi-

* See J. W. Judd, "The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. pp. 719, 720.

† *Loc. cit.*

‡ G. Barrow in "Geology of the Small Isles of Inverness-shire," *Mem. Geol. Survey*, 1908, p. 22.

§ *Op. cit.*, p. 719.

ately north of Faoilean they pass rapidly below sea-level with a high dip, and more massive sandy rock with doggers comes on above. At the mouth of Allt na Dunaiche the coast-line has reached a much higher horizon of the group.

Near Glasnakille, Spar Cave,* opening in a narrow precipitous ravine, penetrates 250 ft. along the line of a dyke.

Inland on the outer ledge small scarps and bare slopes of glistening white sandstone, bleached and decalcified at the surface, rise everywhere from the peaty moorland.

In the north bank of Abhuinn Cille Mhairè, 150 yds. north-west of Kilmarie Lodge, a thin bed not far below the top of the thick sandy group yielded *Pecten articulatus* and associated fossils already mentioned.

Where the road bends eastward at Keppoch (Capach) an excavation in the shale bed, indurated by dykes, afforded most of the ammonite fragments recorded above. No other fossils were found.

Near the middle of the thick sandy group, and lower than the fossil-bed at Kilmarie, belemnites and young oysters were noted in calcareous doggers 300 yds. below the north-easterly bend of the road on its descent to the coast. Not far from the top traces of marine shells occurred half a mile south of Allt na Dunaiche; again far above the basement beds in the gorge by which that stream reaches the shore along a weathered dyke; and also above the road 300 yds. further north.

Of the low-lying tract between Allt na Dunaiche and Allt Aigeinn, heavily encumbered with drift and peat, we can only say that its eastern and northern margins and its north-west corner belong to the Inferior Oolite series; that the south-western half is composed of the Great Estuarine shales; and that the strata curve round synclinally with outcrops convex to the south, as seen in Allt Aigeinn.

The general synclinal structure of the neighbourhood renders it likely that calcareous sandstone with traces of shells at the west margin of Loch na Sguabaidh may belong to the Inferior Oolite; but the prevalent northerly or north-westerly strike leaves little room for the complete sequence between this point and the Lower Lias of Clach Oscar. Probably a fault runs up Srath Mòr.

In the steep lower slope of Sgùrr nan Each the Inferior Oolite sandstones, metamorphosed to a splintery rock of quartzitic appearance and penetrated by tongues of granophyre, are arranged anticlinally. Their lower boundary with the overlying estuarine shales is probably faulted, but higher up the mountain side they dip westward under the same shales. On the south this mountain tract of metamorphosed sandstone seems to be dovetailed into the indurated estuarine shales by several faults.

Certain bands of lime-silicate rock have the aspect of metamorphosed limestone in the higher part of the Inferior Oolite sandstones of Sgùrr nan Each and other places where these strata are much altered. But limestones are scarcely, if ever, seen amongst the higher sandstones

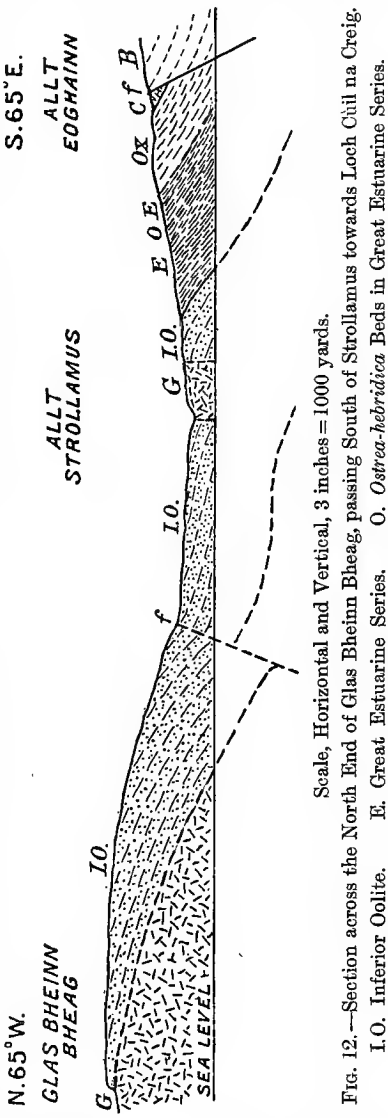
* The cave has been described by K. Macleay, "A Description of the Spar Cave lately discovered in the Isle of Skye," Edinburgh (1811); also by J. Macculloch, "A Description of the Western Islands of Scotland," London (1819), vol. i. pp. 271 *et seq.*

where unaltered in Strathaird; though Macculloch mentions beds of "mere limestone," perhaps oolitic, in the upper part of the series.* It is probable that the more calcareous sandstones, sufficiently decalcified at the surface to appear as sandstones in an unmetamorphosed state, are fixed as lime-silicate rocks when metamorphosed, and subsequently reach the surface with the habit of altered limestones.

Dr. Flett, who has examined a sliced specimen (11251) of one of these rocks from the lower slopes of Sgùrr nan Each, considers that it may represent an original sandy limestone or highly calcareous sandstone.

A little patch, consisting of 4 ft. of blue lime-silicate rock on white grit with small pebbles, intercalated between granite below and basalt above, on the east shoulder of Blathbheinn, probably represents the top of the Inferior Oolite series. But nowhere else in Strathaird does the basalt overstep the Great Estuarine series.

C. B. W.



Scale, Horizontal and Vertical, 3 inches = 1000 yards.

Fig. 12.—Section across the North End of Glas Bheinn Bheag, passing South of Strollamus towards Loch Cùil na Creig.
I.O. Inferior Oolite. E. Great Estuarine Series. O. *Ostrea-hebridica* Beds in Great Estuarine Series.
Ox. Oxford Clay. C. Upper Cretaceous. B. Tertiary Basalt. G. Granophyre. f. Fault.

STROLLAMUS DISTRICT.

The Mesozoic sequence of Strathaird affords a key to the metamorphosed Jurassic rocks of this district, which reproduces the same succession from the Inferior Oolite upwards. From a brief examination of the rocks in 1896, Mr. Woodward inferred that they might represent the Lower Lias (Broadford Beds); † but, owing to the want of definite evidence, he deferred the mapping of the strata.

A great thickness of indurated sandstones ‡ makes a bold ridge above the underlying granophyre along the crest of Glas Bheinn Bheag, bends over eastward with increasing dip down the slope (see Fig. 12), and finally passes under the Great Estuarine shales.

The granophyre is not intruded uniformly at the base, but

* *Op. cit.*, p. 349.
† *Annual Report of Geological Survey* for 1896, 1897, p. 71.
‡ *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, pp. 143–144.

evidently cuts out higher beds southward. Nothing suggests a greater thickness for these sandstones here than in Strathaird; and as no shale was detected in the lower beds, we need not suppose any Lias included. The lowest part of the sequence, hardened, fine-grained, streaky, or laminated sandstones, presents however some difficulty. As such strata seldom occur in the higher part, it might be thought that they represent the lower calcareous flaggy beds of Strathaird. But they have not a calcareous aspect. Dr. Flett describes a sliced specimen (11250) as baked felspathic sandstone, undoubtedly indurated and rendered more compact by the thermal action, but showing few mineral changes.

The upper and greater portion of the sequence, more thickly bedded white altered sandstones with rare pebbly seams, often contains large round bodies, seen when least metamorphosed to be the doggers of calcareous sandstone so abundant in Strathaird. They are chiefly recognised in the higher beds on the lower slope, where burns have channelled the rock. The doggers and the rest of the sandstone not infrequently include hollow moulds of circular outline, representing belemnites, as was clearly shown by a longitudinal section.

A band of black shale, exposed in the upper part of the formation in two or three places, may be at a lower horizon than the shale bed of Strathaird.

In Allt Strollamus, just above the bridge, calcareous beds not far from the top of the series are metamorphosed to white sandy marble amongst altered sandstones.

Higher sandstones and calcareous beds intersected and metamorphosed by granophyre appear again by the roadside for some distance east of the bridge, but soon pass under the overlying shale series.

In the south small patches of sandstone caught up in the lavas of Creagan Dubha, beyond an upthrow fault, probably belong to the Inferior Oolite.

LOCH SLIGACHAN DISTRICT.

North of the loch, 60 or 70 ft. of white granular and somewhat calcareous sandstone with occasional quartz pebbles extends along the shore under Tòrr Mòr and Tòrr Beag for 600 or 700 yds. It passes up through grey micaceous sandstone with few pebbles into thin dark micaceous shale, becoming carbonaceous above, and overlain in the base of the cliff immediately below the basalt by a seam of impure graphite a few inches thick.* This may possibly represent a coal associated with the Tertiary lavas, but the apparent upward passage from the white sandstone into the graphite, renders it more probable that all these beds belong to a conformable series. They seem to be unfossiliferous, but Bryce determined their Inferior Oolite age by showing their relationship to the Upper Lias of the coast further north.†

Mr. Harker noted a small exposure of the same beds under the basalt further west on the north shore of Loch Sligachan.

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 143.

† "On the Jurassic Rocks of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. pp. 319 and 321.

Great Estuarine Series (Loch Staffin Beds).

STRATHAIRD.

A series of different lithological character follows conformably upon the sandy Inferior Oolite. Strikingly poor in sandstone, it consists essentially of black laminated estuarine shales, with blue limestones of two types, chiefly in the upper half.

Strata of this series were discovered by Macculloch * in the north of Skye, and were afterwards noticed by Murchison as the estuarine "Loch Staffin Beds." Subsequently E. Forbes † assigned them to their position below the Oxford Clay. Similar beds have long been known to occur on the north-west coast of Skye, in Raasay, and in Eigg and Muck, where Professor Judd has described them as the "Great Estuarine series." ‡

These estuarine beds crop out continuously around the basalt-capped hills of Strathaird § on all sides but the west, and form the lower slopes above the outer ledge of Inferior Oolite on the east. In the north of the promontory, whence they run along the higher flank of Sgùrr nan Each and Belig, besides descending into the low ground at the head of Loch Slapin and the slope above Srath Mòr, they come directly under the basalt. On the west the Camasunary fault cuts them off or leaves but a narrow strip, while further south they are finely exposed in the seacliffs.

Coast sections and numerous inland exposures enable us to determine a descending sequence, probably about 400 ft. thick and constant in most respects throughout Strathaird, as follows :—

General Sequence of Great Estuarine Series.

		Thickness. Ft.
VI.	Blue shaly marl with blue or white calcareous nodules, up to 30 or	40
V.	(Paludina-scotica Limestones.) Blue fine-grained smooth argillaceous limestones or cement-stones, weathering cream-coloured, contain gasteropods and alternate with shales, fibrous carbonate of lime ("beef"), and thin beds of calcareous sandstone : in the south not less than	37
IV.	Black and blue shales and mudstones with occasional thin limestones : thickness doubtful, perhaps as much as	40
III.	(Ostrea-hebridica Beds.) Calcareous shales or limestones crowded with *Ostrea hebridica* : in the south probably more than	17
II.	(Cyrena Limestones.) Massive blue sandy and often crystalline limestones and calcareous sandstones, full of small lamellibranchs (*Cyrena*) generally crushed together, alternate with dark shales and occasional bands of "beef" : sometimes a bed of *Viviparus* [*Paludina*] cf. *aurelianus* occurs near the top : thickness probably about	70
I.	(Cyrena Shales.) Black laminated shales with numerous beds of *Cyrena* throughout, and occasional thin bands of blue limestone and calcareous sandstone : probably about	200

* "A Description of the Western Islands of Scotland," London, 1819, vol. i. p. 345.

† "On the Estuary Beds and the Oxford Clay at Loch Staffin in Skye," *Quart. Journ. Geol. Soc.*, 1851, vol. vii. p. 104.

‡ "The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 722.

§ *Summary of Progress* for 1900, *Mem. Geol. Survey*, 1901, p. 113 ; *Summary of Progress* for 1901, p. 144.

The horizons of the *Cyrena* limestones, the *Ostrea-hebridica* beds, and the *Paludina-scotica* limestones are indicated on the map by single lines, where they could be traced.

A fauna wholly distinct from that of the Inferior Oolite series comprises very few species, represented by countless individuals; but their bad preservation in the shales, and their packed and crushed condition in the *Cyrena* limestones, make it difficult to recognise other forms probably present.

The lower half, composed almost entirely of black evenly laminated shale of a platy appearance, contains beds full of *Cyrena* apparently of more than one species. The overlying sandy limestones and calcareous sandstones are crowded with the same fossils. But in the south of Strathaird a large "*Paludina*" (*Viviparus* cf. *aurelianus*), resembling a form which Mr. Barrow finds below the oyster beds in Eigg,* occurs in one of the highest of these limestones. Above this group come the beds of dwarf oysters, so remarkably constant over a very wide area, in thin bands of calcareous shale or limestone.

The succeeding strata perhaps indicate different conditions, marked by a palæontological and lithological change. It is doubtful whether the bivalves of the *Cyrena* beds persist above the oyster bands in Strathaird. Gasteropods on the other hand, though they occur in the lower beds, are the common molluscs of the *Paludina* limestones which, while often apparently unfossiliferous, here and there include large numbers of *Viviparus* [*Paludina*] *scoticus*. Mr. Tait found remains of fish and reptiles in the shales associated with these limestones; but one of these fish, *Hybodus grossiconus*, he obtained also below the oyster beds. No fossils were detected in the highest blue marl.

Lithologically the fine-grained smooth compact limestones of the *Paludina* beds, blue in colour, but weathering creamy-white, contrast sharply with the rough crystalline sandy *Cyrena* limestones.

The lower and greater part of the series denotes undoubtedly estuarine conditions. But the change of character in the upper beds, as shown by the smooth-textured limestones and mudstones, indicative of deposition in very still water, together with their peculiar fauna and the scarcity or absence of the typical fossils of the estuarine lower beds, suggests a possible freshwater origin for these higher strata. But in any case, in view of the variability of the series over a wider area, any such differentiation into estuarine and freshwater beds could probably have only a local application.

We have not seen the exact junction of the series with the highest white sandstone of the Inferior Oolite; but black laminated shale was found only 2 or 3 ft. above that sandstone—near enough to show a more rapid upward change from the latter to the estuarine shales, than its downward passage into marine shales.

The whole sequence occurs throughout Strathaird as far north as Faoilean, above which the blue marl and the *Paludina* limestones pass under the basalt of An Càrnach. On the west side also they disappear similarly north of Camasunary. Further north these members of the series, as well as the Oxford Clay, have not been recognised in the district, perhaps owing to metamorphism and paucity of sections. The blue marl at the top retains its full thickness

* See "Geology of the Small Isles of Inverness-shire," *Mem. Geol. Survey*, 1908, p. 21.

in the east and south of the promontory; but it is doubtful whether it does so along the west coast north of Glen Scaladal.

The Great Estuarine series must represent the whole stratigraphical succession from, and perhaps including part of, the *Parkinsoni* zone of the Inferior Oolite formation up to the Oxfordian, if there is no break below the latter.

The estuarine strata of Strathaird belong essentially to the argillaceous and calcareous, as distinct from the arenaceous, development of the series.* Less arenaceous than the corresponding beds in the north of Skye and in Raasay, they contain no equivalent of the great sandstone mass of Eigg, unless the sandy *Cyrena* limestones and calcareous sandstones are its attenuated continuation.

The fine cliff sections in the south-west of Strathaird afford the most complete and accessible exposures of the series in Skye.

At Elgol, north of the white cliff of the Inferior Oolite sandstone, black laminated shales with shell beds and few thin bands of shelly limestone (*Cyrena* shales); a thick group of sandy limestones, calcareous sandstones, and shales (*Cyrena* limestones), forming a lofty cliff which ends in a little promontory; alternations of calcareous shale and limestone crowded with *Ostrea hebridica*; and a group of smooth blue *Paludina* limestones, with intercalated shales, in a smaller cliff, all descend in turn to sea-level, the last named at the mouth of a burn. Thence the coast trends north-north-east, and the blue shaly marl with calcareous nodules, coming on above the limestones, continues on the shore and in the base of the low cliff under sandy Oxfordian strata. But close to the slipped mass at Càrn Mòr the *Paludina* limestones, dipping south of west, emerge again, and the cliff presents a descending sequence as follows :—

Cliff Section at a projecting Bluff immediately South of the slipped Mass at Càrn Mòr, West Coast of Strathaird.

	Thickness. Ft.	In.
Friable blue shale with blue limestone nodules	—	
Hard blue shales with thin bed of light blue muddy limestone or calcareous mudstone	2	0
Blue calcareous mudstone or muddy limestone	1	0
Thin light blue muddy limestones and calcareous shales with large limestone nodules	4	0
Blue muddy limestone, weathering buff, with shaly bands	3	0
Friable blue shale with calcareous shaly bands	3	0
Blue limestone, weathering buff, full of *Viviparus*	2	0
Calcareous shale	0	6
Massive smooth fine-grained dark blue limestone, weathering buff	2	0
Light grey calcareous shale	0	6
Dark blue limestone	1	6
Light grey calcareous shale	1	0
Massive smooth fine-grained blue limestone	1	6
Beds of nodular blue limestone, weathering buff, with partings of shale	4	0
Light grey rubbly calcareous shales with thin nodular limestones and thin bands of "beef"	6	0
Dark grey rubbly shale	2	6
Light grey calcareous shale	2	6
Hard blue limestone	—	

* See J. W. Judd, *op. cit.*, p. 723.

From some of the lower beds of the foregoing section, chelonian and other reptilian bones, fish scales and teeth were obtained.

The seaward dip of soft shales under a load of basalt has produced a landslip. For 500 yds. this has completely buried the cliff under a tumbled mass of basalt, shale and sandstone, below a great gap in the mountain side with rugged precipitous walls.

The upper part of the *Cyrena* limestones has risen into the cliff and begun to sink again northward beyond the fallen mass, between which and the mouth of Glen Scaladal the following sequence, descending southward, is exposed in a distance of 270 yds.:—

Cliff Section from a large Dyke near the Mouth of Glen Scaladal to the Landslip at Càrn Mòr.

		Thickness. Ft.	In.
	Thin basic sill	—	
Ostrea-hebridica Beds.	Blue limestone	2	0
	Blue shaly limestone full of *Ostrea hebridica*	1	0
	Thin limestones and calcareous shales full of *O. hebridica*	2	0
	Blue limestone with *O. hebridica*	1	0
	Calcareous shales and limestones with beds of *O. hebridica*	2	0
	Hard blue calcareous sandstone	1	6
	Calcareous shales with *O. hebridica* and other small lamellibranchs	2	0
	Blue marly limestones with thin shales	2	0
	Basic sill	2	0
Cyrena Limestones.	Shale	0	6
	Massive blue sandy limestone with small lamellibranchs	3	0
	Band of "beef"	0	2
	Sill of porphyritic felsite	3	0
	Obscure, including a basic sill	2	0
	Calcareous shale full of *Cyrena* (?)	1	6
	Basic sill	2	0
	Laminated blue sandy limestone and thin shales full of small lamellibranchs	2	6
	Soft shales and sandy calcareous shales with bands of "beef"	1	6
	Dark blue marly limestone	1	0
	Shales and limestone with small lamellibranchs	1	0
	Shale and "beef"	0	6
	Shelly limestone	0	6
	Calcareous shale with small lamellibranchs	1	0
	Blue sandy limestone (on shore), crowded with small lamellibranchs	2	0
	Basic sill	0	8
	Shale with *Cyrena* (?)	0	8
	Blue sandy limestone with small lamellibranchs: the top is shaly and contains plants (?)	1	6
	Laminated sandy calcareous shale	0	6
	Blue sandy limestone crowded with small lamellibranchs	—	

North of the dyke above mentioned, the oyster beds have a thickness of at least 17 ft. On the foreshore near the south end of the beach at Cladach a' Ghlinne, a blue sandy limestone contains in abundance the large *Viviparus* cf. *aurelianus* already mentioned. Though not identified in the above section, this bed necessarily lies a little lower than the oyster bands; and Mr. Tait found a large *Viviparus* not far below these in the cliff, with *Hybodus grossiconus*, *Cyrena*, *Anomia æstuarina* and doubtfully *Estheria*.

The slope on the south side of Glen Scaladal exceeds in amount the uniform dip of the strata between north-west and north, so that

lower beds crop out downward, with the oyster bands at the bottom.

On the foreshore north of the glen dark blue muddy limestones and mudstones alternate with black shales, and the cliff above affords a fine exposure of the *Paludina* limestone group, similar to the section of these beds south of Càrn Mòr. *Viviparus scoticus* occurs in several of the higher limestones.

On the shore of Camas Fhionnairidh the *Paludina* and *Ostrea* beds, reappearing from beneath Oxford Clay, are bent up at the Camasunary fault with high southerly dip. Metamorphosed blue limestones with *Viviparus scoticus*, blue calcareous sandstones, and altered white sandstones, with black shales, crushed, or metamorphosed to a hard green rock, are separated by a greater thickness of laminated shale with thin limestones from an *Ostrea-hebridica* limestone in the foot of the cliff, where it ends at the fault. Here Mr. Harker found the *Paludina* limestones changed to lime-silicate rocks with diopside and other secondary minerals.* The metamorphism is due to the numerous basic dykes.

Northward in the eastern tributaries of Abhuinn nan Leac we no longer see the *Paludina* limestones, which, like the Oxford Clay, seem to have passed under the lavas. But the oyster bands and the *Cyrena* beds below are exposed at intervals, the former as far as the more northerly dislocation that cuts the Camasunary fault. In the second of the tributary burns northward is a thin blue oolitic limestone, unnoticed elsewhere, not far from the oyster beds.

On the east side of the basalt hills all the important horizons in the series can be traced more or less continuously as far north as Faoilean.

Above Elgol, north of a basic sill, which has baked the marl in contact with it, unaltered blue shaly marl in a little burn contains white and blue calcareous nodules. North-eastward the harder groups of the *Paludina* and *Cyrena* limestones usually make prominent outcrops on the slope. South of Robostan the upper limestones yielded *Viviparus*, but for some distance northward their outcrop is obscured. Just below them a small burn showed blue mudstone with badly preserved little bivalves, different from those of the *Cyrena* beds.

Excavations for the dam of the new trout-loch near the Free Church at Kilmarie exposed the *Cyrena* limestone group, sandy limestones and calcareous sandstones with black shales, all crowded with *Cyrena*, seen also in profusion throughout the lower shales in the stream.

At Kirkibost near the approach to Strathaird House, a small pit showed black shale, full of the usual lamellibranchs, not many feet above the Inferior Oolite sandstone.

A short distance north of Tobar Ceann the blue marl and the *Paludina* limestones, traced almost continuously from Kilmarie, are overstepped by the basalt.

Allt na Dunaiche, in which the general synclinal structure is apparent, affords an uninterrupted exposure of the *Cyrena* shales from a bend where a fault throws them down on the south against the highest sandstone of the Inferior Oolite. The *Ostrea-hebridica* beds are seen as calcareous shales and shaly limestones lying nearly flat in

* "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, p. 309.

the lower of two waterfalls, while, not far below, limestones and calcareous sandstones of the *Cyrena* limestone group crop out. Above this waterfall hardened shales with limestone bands below the oyster beds bend round slowly and irregularly to an easterly and south-easterly dip.

Above the stream and its tributary from Coirê Uaigneich, a bold escarpment consists of calcareous shales and limestones, full of oysters and merging below into sandy limestones and shales with smaller bivalves. Here and on the flank of Sgùrr nan Each, the horizons of the *Ostrea-hebridica* beds and the *Cyrena* limestones are represented by one line on the map. The cliff in the lower part of Coirê Uaigneich shows the *Cyrena* shales with few thin bands of limestone. At the base a metamorphosed bed of lime-silicate rock was seen resting on the steep slope of granite. It reappears with some white sandstone below, both probably belonging to the Inferior Oolite series, at the top of this slope on the west, beneath the basalt.

On the eastward slope north of Allt na Dunaiche and below the outlier of basalt, one of the oyster limestones is so greatly metamorphosed as to pass into a grey mottled marble. Near the north end of the basalt outlier the bivalves of the baked lower shales weather out in relief, and are readily determinable as *Cyrena*.

In the high ground below Clach Glas, the mountain ridge connecting Blath-bheinn with Sgùrr nan Each, granite intrusions and faults have obscured the sequence; but in the most westerly strip of the Great Estuarine series just below the basalt, a burn showed shale and limestone full of oysters.

On the eastern slope of Sgùrr nan Each the *Ostrea-hebridica* beds and the *Cyrena* limestones can be traced continuously, running with north-westerly dip obliquely down the mountain side, in the midst of indurated shales overlying the sandstones of the Inferior Oolite. It is possible that in the absence of exposures some part of the Oxfordian may have been included with the Great Estuarine series on the north-east flank of the mountain.

Granite interrupts the continuity of the beds in the valley of Allt Aigeinn; but the *Cyrena* limestones, with altered shale above and below, are found again to ascend the south spur of Belig and continue along its eastern slope above a strip of granite as far as Loch na Sguabaidh. On the south end of the spur, altered limestones and shales full of the little bivalves are seen arched into small anticlinal flexures; but along its east side the beds assume a steady westerly dip above the granite. Further down the mountain side at the top of the lower slope they dip eastward off the granite, and thin bands of limestone, sometimes baked to white marble, with calcareous sandstone and shale, are exposed at intervals. As the slope exceeds the dip, lower shales crop out below almost down to Loch na Sguabaidh.

The Great Estuarine beds highest on the flank of Belig are continuous northward with a strip of metamorphosed Jurassic rocks of uncertain age, intercalated between granite below and basalt. They have the same westerly dip and continue the strike of the estuarine beds, with which they have been included on the map. But while the rocks in question consist in their lower part of much

altered shales, limestones and sandstones, alternating mostly in thin beds, in one of the water-courses a greater thickness of metamorphosed lime-silicate rock lies just above the granite. Moreover, the upper half of the sequence is chiefly a very hard altered sandstone; and in one place the highest beds showed less altered sandstone with traces of calcareous doggers. It is possible that these metamorphosed rocks may represent the upper part of the Great Estuarine series and the lower sandy beds of the Oxfordian. On the other hand, if faulting could be proved, their sequence is not inconsistent with a Lower Liassic age, on other grounds improbable.

STROLLAMUS DISTRICT.

Here also the Great Estuarine series follows the Inferior Oolite with much the same sequence as in Strathaird. But, as in the north of that district, the *Paludina* limestones and the overlying blue marl were not positively recognised. The shales and most of the limestone bands, even when much altered, are often crowded with small lamellibranchs, occasionally determinable as *Cyrena*, while higher limestones are full of *Ostrea hebridica*.

The basement beds of the Great Estuarine series are seen in Allt Strollamus just below its confluence with Allt na Teangaidh, as hardened black laminated shales with few thin blue limestones. Both are crowded with little lamellibranchs, apparently *Cyrena*, not far above the Inferior Oolite sandstone. The edges of the shales, with regular strike and high south-easterly dip, stand up as ribs in the stream, while the solution of the limestones produces little troughs. Higher shales are seen in the lower part of Allt na Teangaidh, and on the low ground east of Allt Strollamus. In the former burn they contain, besides limestones in the upper part, a fine-grained dark greenish indurated sandstone more than 17 ft. thick, a thicker bed than any noted in Strathaird. Further up the stream bands of limestone full of *Ostrea hebridica* are followed by more shale with few thin limestone bands.

In Allt Eoghainn, the next burn eastward from Allt Strollamus, a granophyre intrusion cuts out the lower shales. Above it higher beds, much altered close to the granophyre, consist of shales and blue limestones. The lower part of the nearest limestone is metamorphosed to a coarsely crystalline white marble with "eyes" resembling spherulitic structures. Yet the upper part of it, as well as the succeeding shales and *Cyrena* limestones, much less altered, is full of the usual small bivalves. Higher in the stream and in the sequence thin limestones and shales contain beds of *Ostrea hebridica*, above which calcareous shale shows again much alteration for a short distance, as though underlying granophyre had approached the surface unevenly.

Along the road east of Allt Eoghainn swallow-holes mark the position of the limestones. The highest shales, with thin limestones, much indurated, pass on the foreshore under Oxford Clay.

In the south of Scalpa the metamorphosed shale is probably not all Oxfordian, though so represented on the map. The lower beds may belong to the Great Estuarine series, but at the time of our visit this was not suspected.

Oxfordian and Corallian.

INTRODUCTION.

The recognition of Oxford Clay by E. Forbes * at Loch Staffin, and by Bryce † at Uig, between which places it was found to extend continuously around the north coast of Skye, and its subsequent description by Professor Judd ‡ in Eigg, left a great interval in which this formation was not known to occur. The recent survey has proved its presence in Strathaird, at Strollamus and in the south of Scalpa.§

STRATHAIRD.

Marine shales, calcareous grits and sandstones of the Middle Oolite succeed the Great Estuarine series abruptly. They cover a relatively large area in the central and south-western parts of the promontory, and crop out immediately beneath the basalt, except at one place, where a narrow fringe of Cretaceous rocks intervenes. The Middle Oolite consists in its lower part chiefly of earthy or shaly, calcareous and micaceous sandstones and grits, dusky or brown on a weathered surface, but blue inside. These contain shaly beds and pass upward into a more argillaceous type of rock with dark grey or blue micaceous shale and sandy shale predominating over more arenaceous strata. The basement beds in Strathaird, generally coarse-grained and often pebbly, present now and then a striking appearance : dark calcareous and micaceous grits contain numerous water-worn pebbles of white quartz and quartzite, sometimes more than an inch in length, and abundant moulds of dissolved belemnites.

On the south-west coast the series may attain a thickness of 300 ft., of which about 80 ft. may be assigned to the most sandy lower beds. But northward the lavas transgress the base of the Oxford Clay and pass on to the estuarine strata above Druim an Fhuarain on the east side and above Camasunary on the west. Probably, too, a slightly less degree of synclinal folding in the Tertiary basalts than in the Jurassic beds accounts for the preservation of a greater thickness of Oxfordian and Corallian strata in the middle of the trough. Hence we find evidence of the highest beds occurring along the west side of the central valley, and on the west flank of Beinn Leacach. The basalt sheet of Ben Cleat and Ben Meabost, except at its south-west end, rests on the lower sandstones.

Fossils are most abundant in the lower beds. Fragments of wood and other plant remains attest the proximity of land.

From loose blocks of calcareous sandstone at the foot of the sea-cliff south of the landslip of Càrn Mòr, Mr. D. Tait obtained a series including *Ornithella kellowayensis*, *Rhynchonella* cf. *varians* in great

* " On the Estuary Beds and the Oxford Clay at Loch Staffin in Skye," *Quart. Journ. Geol. Soc.*, 1851, vol. vii. p. 104.

† " On the Jurassic Rocks of Skye and Raasay," *Quart. Journ. Geol. Soc.*, 1873, vol. xxix. p. 331.

‡ The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands," *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv. p. 726.

§ *Summary of Progress* for 1900, *Mem. Geol. Survey*, 1901, p. 113 ; *Summary of Progress* for 1901, p. 145.

profusion, *Protocardia crawfordi* and *Kepplerites gowerianus*, essentially a Kellaways fauna and widely different from that of the rest of the Oxfordian, *Pecten fibrosus* and *Pseudomonotis* cf. *ovalis* being alone common to both. This sandstone had evidently fallen from the Oxfordian outcrop on the brow of the cliff, but was not found in place. Here, if nowhere else, a remnant of Kellaways age is preserved, either beneath the Upper Oxford Clay, or less probably as *remaniés* blocks incorporated in it. No trace of *Ornatus* beds was detected, while throughout Strathaird a characteristic Upper Oxford fauna of cordate ammonites (*Cardioceras cordatum*, *C. nikitinianum* ?, *C.* cf. *rotundatum*, *C. rouilleri*, *C. suessi*, *C. tenuicostatum*, *C.* cf. *vertebrale*) with belemnites, *Pecten fibrosus*, *Pholadomya* and *Pseudomonotis* cf. *ovalis*, comes in close to the base of the formation. At an uncertain distance below the top of the sandy beds this fauna mingles with a group of distinctly Corallian aspect, in which, amongst numerous other cordate forms, *Cardioceras excavatum* appears together with *Perisphinctes pseudoplicatilis* ?, *P. variocostatus* ?, *Belemnites abbreviatus*, *Pecten* cf. *comatus* and *Pholadomya* cf. *æqualis* ; while a large broad *Gryphæa*, *Modiola bipartita* ?, *Pinna mitis* and *Pecten demissus* ? also occur. In the upper course of Abhuinn Cille Mhairè, where the elevation of the ground and its position in the synclinal trough suggest a high horizon, a group of ammonites was obtained with *Perisphinctes* predominating (*P. mogosensis* ?, *P. pickeringius* ?, *P. suevicus* ?, *P. variocostatus* ?, *Cardioceras* cf. *quadratum*). *Cardioceras* is present in the highest beds beneath the Cretaceous of Strollamus.

Apart from the Callovian remnant already described, the whole formation consists of a high horizon of the Oxford Clay (*Cordatus* zone), passing upwards into beds of Corallian age. The latter could scarcely be differentiated, and the whole was represented as Upper Oxford Clay on the one-inch map ; for, at the time this was prepared, the Corallian evidence did not appear quite conclusive.*

The abrupt change from the fine sediments of the Great Estuarine Series to the pebbly sandstones of the overlying marine formation raises the question of unconformability. But from north to south of Skye the marine sandstones rest upon a high horizon of the estuarine series, if not upon its highest member throughout ; † and there is less reason to suspect an unconformable break between the estuarine and the marine strata, than to assume such an interruption of the sequence following the deposition of the Kellaways Rock and resulting in the removal or exclusion of that rock and the Lower Oxford Clay.

The strata, much indurated in the northern part of their outcrop, give the impression of being slightly hardened everywhere in Strathaird. They rarely, if ever, appear as plastic clay, though described as such at Uig, and in Eigg as similar to the English Oxford Clay. The blue shales seen at Strollamus would evidently be of such a nature, if not hardened.

Fossils are seldom or never found to be pyritised, and nodules of pyrites rarely occur. On the other hand laminæ or films of gypsum were noted, especially in the blue shales at Strollamus, but no crystals of selenite.

* See "Geology of the Small Isles of Inverness-shire," *Mem. Geol. Survey*, 1908, pp. 28, 29.

† See, however, *op. cit.* p. 30.

The seacliffs of Beinn Leacach and the flank of Ben Cleat above the landslip afford the best sections.

On the west coast north of Elgol, where the loose blocks with a Kellaways fauna were found on the shore, the sandy base of the Oxford Clay comes down into the upper part of the cliff, in which it continues northward nearly as far as the landslip. Above this at Càrn Mòr the rent hillside gives fine exposures of shaly and calcareous sandstone and micaceous shale. A bluff of shaly sandstone some distance from the base and above the slipped mass contains *Cardioceras rouilleri*, *C. excavatum*, and *Pecten* cf. *comatus*, while from the same or a slightly higher horizon *Cardioceras cordatum*, *C. funiferum* ?, *C.* aff. *nikitinianum*, *C. quadratoides*, *C. suessi* and *C.* cf. *vertebrale* were obtained.

A little burn on the north-west flank of Ben Meabost exposes the dark calcareous basement grit, with large white pebbles of quartz and quartzite. *Perisphinctes* sp. was met with higher.

Glen Scaladal is cut through to the estuarine beds, but its upper part is drift-covered. The base-line there drawn for the Oxford Clay, exposed on both sides of the glen, is conjectural.

North of Glen Scaladal the bottom of the series sinks slowly below sea-level, and the sandy lower portion, here estimated at about 80 ft., is admirably exposed in the cliff as far as Rudha na h-Airidh Bàine, where it passes below the shore. Grey, earthy and micaceous sandstone, calcareous where unweathered, forms the cliff and contains small pebbles in its lower part and cordate ammonites throughout, with *Perisphinctes variocostatus* ? in its upper strata. Some beds are crowded with belemnites. A gently shelving ledge of dark sandstone, stained red and brown with iron, is covered with these fossils, often of great size, and presents a remarkable sight. The belemnites, lying in all directions, stand out in relief, sometimes dyed red, sometimes pure white through solution of their surface.

Soft shales succeed the sandy beds. The strata bend round synclinally from a north-easterly to a south-easterly dip, southerly near the Camasunary fault. For most of the distance from Rudha na h-Airidh Bàine to the fault, micaceous shaly beds with belemnites are seen : but near it the sandy strata reappear.

Along the eastern outcrop the lower beds in the hollow between Ben Cleat and Ben Meabost afforded *Cardioceras cordatum*, *C. nikitinianum* ?, *C.* cf. *rotundatum*, *C. rouilleri*, *C. suessi*, *C. tenuicostatum* and *Perisphinctes laufenensis* ?.

Northward beyond a talus-covered slope pebbly sandstone with belemnites crops out on the east flank of Ben Meabost. At Robostan by the footpath the base is a dark shaly and flaggy sandstone with large white pebbles and belemnites.

The sandstones occur on the north end of Ben Meabost and in the low ground traversed by Abhuinn Cille Mhairè and its tributaries; but the slope rising westward to the basalt escarpment between Geal Ghillean and An Dà Bheinn is composed of higher dark micaceous shale and sandy shale with belemnites.

In the upper part of the valley of Abhuinn Cille Mhairè the Oxfordian strata, much indurated, consist of dark micaceous shales with some shaly sandstone. Now if the base of the Oxford Clay were overstepped

by the basalt in a straight line between the points where this overstep is visible on both sides of Strathaird, the most northerly beds seen in Abhuinn Cille Mhairè might be the lower sandstones. But owing to the synclinal structure the Oxfordian base must curve far to the north between these two points; and we probably meet with higher strata, on the whole, northward up the stream. The low dip veers gradually from west to south by west, and co-operates with the slope to bring in still higher shales with some sandstone on the west side of the valley. These contain many belemnites and occasional *Perisphinctes*, while the above recorded group of *Perisphinctes* and *Cardioceras* was obtained from the stream 50 yds. below the outcrop of the basalt.

From Abhuinn Cille Mhairè the base of the Oxfordian strikes north-eastward above Keppoch (Capach). Shales, seen at first above the sandstones, are soon lost under the basalt. But the lower sandstones and sandy shales with *Cardioceras*, belemnites and other fossils, are exposed in burns, until they too disappear under the lavas.

To the north of Strathaird metamorphosed Oxfordian beds may possibly occur unrecognised above the Great Estuarine Series.

STROLLAMUS AND THE SOUTH OF SCALPA.

Shales, generally much indurated and dark in colour, overlie the Great Estuarine Series with a high dip, south-easterly at Strollamus, but more easterly in Scalpa.

The highest beds seen under the Cretaceous in Allt Eoghainn (the next burn eastward from Allt Strollamus), less altered blue shales with laminæ of gypsum, contain a few cordate ammonites and obscure lamellibranchs. Occasional belemnites occur in their lowest part. Hardened sandy strata make a small feature below, but higher than the oyster beds of the Great Estuarine Series, and probably belong to the Oxfordian.

On the foreshore, just west of Allt an Doire, highly indurated shale afforded two or three casts of a *Perisphinctes*. The exact line of junction with the estuarine beds, seen lower, is uncertain. In the valley of a burn which reaches the sea near Sgeir Stapaig, thick indurated shale is exposed on the coast of Scalpa, and passes under Cretaceous beds. About 50 yds. east of the mouth of the burn, near a projecting dyke, the altered shale contains *Cardioceras* and *Perisphinctes*, with obscure belemnites and lamellibranchs. The shale is seen almost continuously in the burn; also in reef-like ribs on the slope above. Immediately north of the valley two little inliers of it appear amongst the lavas. C. B. W.

CHAPTER XI.

UPPER CRETACEOUS.

In the valley of Allt Stapaig, in the south of Scalpa, thin Cretaceous rocks * emerge from under the basalt. By the roadside, where the outcrop descends to the shore close to Sgeir Stapaig, the following downward sequence succeeds Oxfordian shales, the exact junction with which was not seen :—

Section by Roadside East of Mouth of Allt Stapaig, Scalpa.

	Thickness. Ft.	In.
White, yellowish and brownish sandstone with siliceous veins : a band of dark chert nodules at the base	9	0
Altered and irregularly crystalline light blue limestone : harder and more compact patches stand out like cherty nodules ..	7	0
Hard, coarse, blue, calcareous grit, weathering buff : pebbles of quartz and also limestone : *Exogyra* cf. *conica ; Pecten asper ; Spondylus* sp. ; *Micrabacia* ?	2	0

Extending northward to the head of the valley, these beds are then faulted down ; but beyond there a little inlier of the limestone rests upon Oxfordian shale, while still further a strip of the same sandstone and limestone, much metamorphosed, is let down between Torridonian rocks and quartz-felsite on Mullach nan Carn.

Above Strollamus on the coast of Skye the limestone reappears for a quarter of a mile, but not the overlying sandstone, nor the calcareous grit below. At Allt Eoghainn, the next burn eastward from Allt Strollamus, the limestone, some 15 ft. thick, contains fragments of *Inoceramus*. A slight gap obscures its contact with the Oxfordian.

In Strathaird, east of Geal Ghillean, blue sandy limestone passes down into dark blue, coarse, calcareous grit with small pebbles of quartz and large ones of Oxfordian sandstone. These suggest previous erosion in the neighbourhood, for the rock lies above the higher Oxfordian shales. Six feet of it, dipping north-west beneath the basalt, afforded no macroscopic fossils except a coral-like fragment. Its precise relationship to grey sandstone of the same formation with cherts and small quartz pebbles, close to it and to the basalt, was not clear. In a burn further south at the footpath grey cherty sandstone lies above Oxfordian shale.

Mr. Newton observed a microscopic resemblance of these limestones to chalk ; and Mr. W. Hill has kindly examined sliced specimens from all the localities. He states that those of the Strollamus limestone leave no doubt in his mind that the rock is a remnant of the Chalk, the alteration of the deposit from a dense limestone like the Chalk of

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 145.

England being obvious. He recognises *Globigerina* with Textularian, Rotalian and Nodosarian foraminifera, prisms of *Inoceramus* shells, and with less certainty fragments of plates of an echinoderm and occasional grains of glauconite.

Nothing was seen like the Hibernian Greensand and the glauconitic sand near the Sound of Soay,* but dark cherty nodules associated with the latter resemble those at the base of the sandstone in the Scalpa section.

In a slice of the Strathaird limestone, where it begins to pass into calcareous grit, Mr. Hill finds, mixed with mineral grains, chiefly of quartz, an accumulation of fragments of calcareous organisms, mostly shell (*Ostrea* or *Inoceramus*), with spines of echinoderms, pieces of bryozoa, and probably of *Lithothamnion*, suggesting formation as a reef : the whole is cemented by a calcareous paste, now finely granular crystalline calcite, which has certainly all the appearance of Lower Chalk : this fine material, while infilling the interstices of the coarse fragments, also occurs in *lacunæ* of considerable area in various parts of the slide, and contains *Globigerina* with a Textularian, probably *T. minuta*, also a few " spheres " which agree in aspect with those of the Chalk.

He considers the chalk filling the *lacunæ* and interstices of the

The Cretaceous in Scalpa, Skye and Eigg illustrates in an extreme degree the occurrence of Scottish Secondary rocks only as remnants saved by special protective agencies from complete destruction.* Here, where older Mesozoic strata extend relatively far from the protection of more durable masses, the youngest Secondary beds, when spared by pre-volcanic denudation, are seen only in the narrowest fringe below the basalt outcrops; or, on Mullach nan Carn, as a little shred squeezed in amongst harder rocks. C. B. W.

* See J. W. Judd, *op. cit.* pp. 666 *et seq.*

CHAPTER XII.

TERTIARY IGNEOUS ROCKS.

INTRODUCTION.

Igneous rocks of Tertiary age play a very prominent part in this sheet of the map, and especially in its western portion. West of a line drawn across Skye at its narrowest place, viz. from Broadford to Loch Slapin, rocks of this group, extrusive and intrusive, make up by far the greater part of the ground; while they are represented by minor intrusions, usually in the form of dykes, in the remaining south-eastern part of Skye, in the neighbouring smaller islands, and on the adjacent mainland of Scotland. Further, it is highly probable that Tertiary basalt lavas have at one time extended considerably eastward of their existing relics, and have been subsequently removed in great part by erosion during later Tertiary time.

The undestroyed relics of the lavas overlie rocks as high in the geological sequence as the Jurassic and Cretaceous. The age of these igneous rocks is fixed more precisely by considering them as a closely related natural group, and by regarding this area as only part of a very extensive region over which like conditions prevailed. The basaltic lavas of Skye are inferred with a high degree of probability, to be contemporaneous with those of Mull and Canna, which have yielded an Eocene flora. They represent only one term, and that almost the first, in a long sequence of episodes, which was probably prolonged into Miocene times. There are no data to fix with precision the epoch of the close of igneous activity in this area; but it is to be remarked that the vast amount of subaërial erosion of which the country gives evidence, which must have been a work of long duration, was almost completely accomplished before the Glacial epoch.

The following tabular scheme summarises the chief stages in the progress of Tertiary igneous activity in this area:—

I. *Volcanic Phase.*
   1. Volcanic Agglomerates, representing explosive outbursts at certain centres in what is now the mountain district of Skye.
   2. Basalt Lavas (with some of augite-andesite) forming a vast lava-field, of which only relics are now preserved.

II. *Plutonic Phase.*
   3. Gabbro of the Blath-bheinn range, etc.
   4. Granite and Granophyre of the Red Hills.

III. *Phase of Minor Intrusions.*
   5. Dolerite Sills, intruded chiefly in the basalts, but also in the older subjacent strata.
   6. Acid Dykes and Sheets, including some (probably of rather earlier epoch) which occur in peculiarly intimate association with basic dykes and sills.

7. Basic Dykes, usually with directions not departing widely from N.W. to S.E. The majority of the basic dykes, while belonging to several distinct epochs, fall into this place in the succession: there are, however, some belonging to earlier epochs (2 and 5), and others later than the following (8).
8. Minor Basic Intrusions confined to the gabbro area of Blath-bheinn etc., and taking the form partly of dykes, partly of inclined intrusive sheets.
9. Peridotite Dykes in the Strathaird peninsula. To the same epoch may perhaps be referred certain other ultrabasic intrusions in the area.
10. Trachyte and Trachy-Andesite Dykes in the eastern part of the area. The age of these and of the next succeeding groups relatively to 8 and 9 cannot be fixed with certainty, since they in no case occur in the same district.
11. Augite-Andesite Dykes and others of Acid Pitchstone, the two groups being apparently in close relationship. These dykes are comparatively few.

Following, as far as is possible, the chronological order thus indicated, we shall briefly notice the several rocks in turn. Petrographical details would be out of place in such a general account, and have been sufficiently dealt with in a special publication.*

VOLCANIC AGGLOMERATES AND TUFFS.

Volcanic activity in this region was at first strictly localised and of a more or less paroxysmal character. The products referable to this early stage are mainly agglomerates, consisting of fragments, sometimes ranging up to blocks several feet in diameter but usually smaller, set in a dull greenish matrix. This finely divided matrix is of basaltic material, while the enclosed fragments and blocks are partly of basalt, partly of non-volcanic rocks.

Three distinct centres may be distinguished. The most interesting is that which lies immediately north-west of Loch Kilchrist; for here we have exposed the actual vent of the old volcano, filled with volcanic agglomerate, mostly of a very coarse type, with large blocks of basalt and Jurassic sandstones. It occupies a roughly elliptic area about two miles in diameter; but has been encroached upon on the north side by the granite of the eastern Red Hills, while a more peculiar acid intrusion has found its way up the sides of the funnel and spread into the agglomerate. Making abstraction of these later intrusions, it is evident that the cylindrical mass presents nearly vertical boundaries to the Cambrian dolomites through which it has been drilled. Bedded agglomerates and coarse tuffs, doubtless derived from this vent, are seen to the north-east, about Allt Beinn Deirge, and also extend to the north-west, being exposed on the east side of Srath Beag. They suffice to prove that the outbreak occurred at the beginning of volcanic activity in this district. Relics of agglomerate are also found near Creag Strollamus, further north, chiefly as patches entangled in the later intrusions.

A second considerable mass of volcanic agglomerate occurs on the north slopes of Belig and in Coire Choinnich and Coire na Seilg. It has a lenticular shape, rapidly thinning away both eastward and westward. On the north it is underlain by the granite of the Red Hills, intruded along its lower surface. On the southern or upper

* "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904.

boundary it is in part invaded by the gabbro of Garbh Bheinn, but on Belig it is succeeded in natural position by the basaltic lavas. An interesting feature is that, in addition to the predominant basalt, there are fragments of gabbro and of granitic rocks, which must have been derived from concealed sources.

The third principal area of agglomerate, including also some fine tuffs, is on the western edge of the map, occupying part of the slope of Druim an Eidhne towards Srath na Creitheach. This, too, has fragments of gabbro as well as of basalt. As in the preceding case, the original mode of occurrence is obscured by later plutonic intrusions. In these two occurrences the actual vents are not exhibited, but are probably concealed beneath the accumulations themselves.

BASALT LAVAS.

Although there is little doubt that a large part of the country has once been overspread by a great outpouring of basic lavas, the prolonged erosion which has since affected this region has left here only a few relics of these rocks. The large continuous area of basalt which occupies all the western and northern parts of Skye enters this sheet of the map in the north-west corner. Strips of basalt in a more or less metamorphosed state occur on the borders of the large plutonic masses, as about Glamaig and on the eastern side of the Blaven range. Outliers of the lavas, again, form the hills in the Strathaird district, and other outliers, preserved in consequence of faulting, are found to the north of the eastern Red Hills and in the southern part of Scalpa. Elsewhere these rocks have in general been removed. There are, however, in addition some patches enclosed within the granitic tract, the largest being that on Beinn na Crò.

There is no indication of the existence of central volcanoes after the epoch of the volcanic agglomerates; and it appears that the basalts were extruded, as maintained by Sir A. Geikie, through numerous fissures in the form of small flows, which overlapped and overlay one another, and built up a very considerable total thickness. About 1600 ft. thickness is shewn on Scalpa, although the succession is not fully represented.

The greater part of these lavas are of truly basic composition, being basalts with, or sometimes without, olivine. Some flows, however, are more precisely described as augite-andesites. The rocks are finely crystalline and of dark colour when fresh, becoming dull and greenish-grey by weathering. Most of them are amygdaloidal, the commonest contents of the vesicles being various minerals of the zeolite group.

That these basic lavas were poured forth under subaërial conditions is inferred from the occasional indications of old land-surfaces at various horizons in the group, sometimes with scanty and ill-preserved remains of terrestrial vegetation. More rarely there may be detected contemporaneous fluviatile conglomerates intercalated among the basalts. The only noteworthy occurrence within this sheet of the map is near Loch Cùil na Creag, a little west of Creag Strollamus, where river-conglomerates are seen at two horizons near the base of the group. The pebbles are largely derived from the underlying Torridon sandstone.

GABBRO OF THE BLATH-BHEINN RANGE AND OF THE BROADFORD DISTRICT.

Two considerable masses of gabbro are found within the limits of this sheet, of which one builds the principal mountain group, including Blath-bheinn and its neighbours, while the other occupies lower ground to the west and north-west of Broadford. Two or three small masses occur in addition, one forming the island of Guillamon, between Broadford Bay and Scalpa, and others near Knock, in the Sleat district.

The first-named and principal mass of gabbro is in reality a portion of the great laccolitic intrusion which forms the Cuillin Hills further west (sheet 70). This large body is trenched upon in this neighbourhood by the granite of Marsco and Ruadh Stac; but the gabbro may nevertheless be followed continuously by Sgùrr na Stri, across Srath na Creitheach, and thence in a N.N.E. direction, building Blath-bheinn or Blaven (3042 ft.), Clach Glas, Garbh Bheinn, and the western parts of Sgùrr nan Each and Belig. The rocks composing these mountains consist of labradorite, augite, usually some olivine, and a titaniferous iron-ore mineral. They vary as regards the relative proportions of these minerals, and also in respect of texture; and these variations are due chiefly to the fact that the large mass is built up by numerous irregular and interlacing sheets representing distinct intrusions. Some patches of gabbro within the granitic tract are probably to be regarded as detached relics of this main body, the largest being a sheet-like intrusion which gives rise to some prominent buttresses at the north end of Beinn na Crò. It has been intruded among basaltic lavas, and both rocks have been subsequently enveloped by the granite.

The gabbro of the Blath-bheinn range has been intruded near the base of the basaltic lavas, in one place touching the subjacent Jurassic rocks, and the way in which the basalts pass under the plutonic rock is very evident along the eastern flanks of the mountains. The second principal mass of gabbro—that of the Broadford district—illustrates a very different mode of occurrence, having the habit of a highly irregular boss. The rock which it intersects is the dolomitic limestone of the Cambrian, and the boundaries are of a very intricate kind in ground-plan, the gabbro enclosing very numerous patches of limestone, down to a few yards in diameter. In every place, however, the gabbro cuts cleanly through the limestone with a vertical junction. Only to the northward, on Creag Strollamus, where the gabbro enters Torridon Sandstone, does this habit give place to that of an irregular sheet. The metamorphism of the dolomitic rocks by the gabbro is of a very interesting kind. This gabbro of the Broadford district is less variable than that of Blath-bheinn, and is free from olivine.

GRANITE OF THE RED HILLS.

Granite, including its granophyric and locally felsitic modifications, covers an area of nearly 20 sq. miles on this sheet of the map, mostly in the north-western quarter. A large continuous tract of this rock occupies most of the ground west of Srath Beag, to the limit of the sheet and beyond, with a prolongation into the western part of Scalpa.

Contiguous with this to the east, though almost detached, is a roughly oval area, about two miles in diameter, including Beinn na Caillich and the other eastern members of the Red Hills ; and south of this is the isolated boss, nearly three miles in length, which builds Beinn an Dubhaich. Smaller subsidiary intrusions need not be separately mentioned.

The geological relations of the large granite mass are somewhat variable. Viewed as a whole, it has the general form of a great laccolitic sheet ; and this is well shown towards the south, where the tapering mass passes beneath the gabbro of the Blath-bheinn range, and reappears as a discontinuous belt on the other side. In many places, however, the granite cuts steeply across the rocks in which it has been intruded, viz. the basaltic lavas and sometimes the underlying Jurassic and Torridonian strata. The rock has sometimes a typical granitoid structure, but there is a very general tendency to micrographic intergrowth of the felspar and quartz. A modification of texture is only occasionally to be observed as a marginal phenomenon. On Glas Bheinn Bheag the edge of the intrusion is beautifully spherulitic ; while in the northern part, about Meall a' Mhaoil, the rock becomes a quartz-felsite. The ferro-magnesian elements are hornblende and augite, singly or together, and sometimes also biotite.

The mass which forms Beinn na Caillich etc., has the boss-shape, though its north-western limit is determined by a fault, and there has probably been differential movement also along the southern boundary. On the east side the granite is intruded in contact with the gabbro boss already described.

The Beinn an Dubhaich granite, intruded with vertical junction through Cambrian dolomitic limestones, presents precisely the same remarkable relations as the gabbro boss already mentioned. The metamorphism of the calcareous rocks will be noticed under another head. The plutonic rock here is more typically granitoid than in the other occurrences, and it often contains brown mica in addition to hornblende.

RELATIONS OF THE GRANITE TO BASIC INTRUSIONS.

The posteriority of the granite to the gabbro is demonstrated wherever the junction of the two rocks is clearly exhibited ; but the relations show some interesting points of difference in different localities. At Druim an Eidhne, on the extreme western border of this sheet of the map occur certain dykes with the petrographical characters of spherulitic rhyolites. These are better studied in the adjoining sheet (70), where they are seen to be offshoots from the large granite mass, which itself assumes like characters in its marginal part. The dykes intersect the gabbro as well as the volcanic rocks which are here interposed between the two plutonic masses. The phenomena here give evidence of rapid chilling in the marginal portion of the granite intrusion, and point to a considerable interval of time separating this from the gabbro.

At other places, and especially in the interior of the granite tract, the acid intrusion has apparently followed the basic one very closely, and we find evidence of noteworthy mutual reactions between the two. The small patches of gabbro enveloped in the granite are not

only metamorphosed, with partial or total conversion of the augite to hornblende, but also impregnated in varying degree with the acid magma, so that an abnormal quartz-bearing gabbro has often been locally produced. Similar effects are observable near the junction of the gabbro of the Broadford district with the granite of the Beinn na Caillich mass. In a group of occurrences, probably with subterranean continuity, situated to the north and west of Loch Kilchrist, the mutual reactions between the two rocks have proceeded further. These intrusions occur within, and on the border of, the large cylindrical mass of volcanic agglomerate already described, and they consist essentially of a rather coarse granophyre crowded with débris of gabbro. These latter are in a partially digested state and acidified by the acid magma which has pervaded them, while the matrix has suffered modification in the opposite sense, being abnormally enriched in the ferro-magnesian minerals.*

Another place where remarkable relations are exhibited is on the slopes of Marsco. Here occur, as shown on the map, certain long narrow strips of gabbro (or of rock representing gabbro), which have the general form of dykes. They are probably to be regarded as the feeders of the overlying portion of the gabbro laccolite, of which a small outlier is preserved on the summit-ridge of the hill. They have been enveloped by the subsequent invasion of acid magma, and their substance greatly modified in the sense of acidification. In many places the adjacent granite or coarse granophyre is seen to enclose dark spots, which are xenoliths or relics of gabbro in various stages of dissolution, their outlines gradually fading away until we have merely a dark granophyre unusually rich in the more basic minerals. It seems not improbable that here the gabbro was still at a high temperature, and perhaps barely consolidated, when it was invaded by the granite magma. This supposition is confirmed by the occurrence, in intimate association with the enclosed strips of gabbro, of a peculiar hybrid rock, to which we have given the provisional name marscoite.† This clearly represents a basic magma, probably identical in origin with the gabbro, partly acidified by accession of granitic material prior to its intrusion. Scattered quartz-grains are seen side by side with the prominent crystals of labradorite, and some quartz and alkali-felspar also occur in the ground mass. The marscoite forms dyke-like intrusions interposed between the gabbro and the granite. It is sometimes not very sharply divided from the former rock, while again it has been in places attacked by the acid magma.

That the marscoite is not due mainly to mingling subsequent to intrusion, but represents distinct injections, is further shown by its occurrence in the form of several sheet-formed masses at places further north. On Glamaig it has been intruded as sills in the basaltic lavas, and portions of these sills subsequently enveloped in the granite mass which runs obliquely up the hill. The acid rock is in places crowded with little ovoid patches or spots, which are partially digested débris of marscoite, here further acidified and with a corresponding basification of the enclosing matrix. The phenomena are well shown at the

* For detailed description see Harker, "On certain Granophyres modified by the Incorporation of Gabbro Fragments, in Strath, Skye," *Quart. Journ. Geol. Soc.*, 1896, vol. lii. pp. 320–328.

† The relations are described at length, with petrographical details, in the special Memoir on "The Tertiary Igneous Rocks of Skye," Chapter XI.

northern end of Druim na Ruaige, where an outlying portion of a thick sill of marscoite is completely surrounded by granite. The spotted rock, with gradual passage into an apparently homogeneous but unusually dark granophyre, may be studied at the base of the escarpment formed by the sill.

COMPOSITE (BASALT-GRANOPHYRE) SILLS AND DYKES.

Certain peculiar intrusions consisting of basic and acid rocks in intimate association must be mentioned, although a petrographical account of them cannot conveniently be included in this place.* They are found along the curved belt of Liassic and Triassic strata which extends south and south-west from Harrabol, near Broadford, to Suishnish Point. Good examples may be examined on the Heast road, south of Braigh Skulamus, and on the ridge of Cnoc Càrnach. The typical constitution of the sills is that of a thick sheet of granophyre having thinner sheets of basalt above and below. The acid rock is the later, for it veins the basalt and encloses partially destroyed débris of it; but the basalt is also acidified in greater or less degree towards the junction, and often contains quartz-grains and corroded crystals of alkali-felspars derived from the granophyre magma. The explanation seems to be that a basalt sill, while its interior portion was still only partly consolidated, was invaded by an intrusion of acid magma, which thus came to form a central band, partially destroying and incorporating the basic rock. In the larger composite sills of Beinn a' Chàirn and Càrn Dearg, with a total thickness of 150 to 200 ft., the granophyre greatly preponderates over the basalt, and the latter has in places been totally destroyed. A like departure from the typical triple symmetry is seen in certain composite dykes, near Loch na Starsaich and elsewhere, which have doubtless served as feeders to the sills. One composite sill, well exposed at Rudh' an Eireannaich, the westerly point of Broadford Bay, differs in two respects from the rest. The acid member here is not a granophyre, but a more felspathic rock devoid of quartz; and there is no sharp division between it and the basalt which forms the top and bottom, but a perfectly graduated transition. We may suppose that the interval between the two intrusions was briefer here than in the other composite sills.

DOLERITE SILLS.

The sill-intrusions of basic rocks in this area do not all belong to one epoch. The earliest ones, however, are referable to one great group, which is by far the most important, and its date can be fixed soon after the latest plutonic intrusions (granite etc.). This group is developed in extraordinary force in the northern and western parts of Skye, where the sills occur principally in the basaltic lavas. In the north-west corner of this sheet of the map, the basaltic ground to the north of Loch Sligachan is made up of alternations of the lavas with intrusive sills of the great group, the latter constantly forming strong escarpments. On the other side of the loch, towards the granite of Glamaig, the sills are wanting. This is owing to the fact that the

* See "Tertiary Igneous Rocks of Skye," Chapters XII., XIII.

lavas, hardened by metamorphism and deprived of their bedded character, afforded no easy planes of intrusion. Similarly the sills are well represented in the basalt outliers of the Strathaird district, and to a less extent in the Jurassic strata beneath, but die out as we approach the gabbro of Blath-bheinn. Further east sills, usually of no great thickness, in the Jurassic are probably referable in part to this group ; but there is no clear evidence of its extension far in this direction, and some of the sill-formed intrusions at various points in the Sleat district probably belong to later dates. The sills of the great group consist generally of olivine-dolerite, though the thinner occurrences are of finer texture, and may be styled basalt.

ACID DYKES AND SHEETS.

Dyke-formed and sheet-formed minor intrusions of acid rocks, though much less abundant than basic dykes and sills, are found in numerous parts of the area included in the western half of this sheet. They do not all belong to a single epoch. Some are, as has been remarked, offshoots from the granite of the Red Hills ; and the same relation may perhaps hold for other acid dykes in the mountain district of Skye, although their continuity with the plutonic rocks is not exhibited at the surface. Of somewhat later age are the acid rocks which enter into the constitution of the remarkable composite sills and dykes. The majority of the minor acid intrusions belong again to a later epoch, subsequent to that of the great group of dolerite sills. They affect the Red Hills and a bordering belt, including Scalpa and Strathaird, but are not generally found south of Ord nor east of a line through Breakish (near Broadford) and the head of Loch Eishort. They are mostly dykes ; and when they assume the form of sheets they are less regular in their behaviour than the basic sills.

Petrographically, many of the rocks of this group are spherulitic granophyres ; while others are quartz-felsites with a microcrystalline to cryptocrystalline ground mass. Less commonly occur rocks of more felspathic composition, with little or no quartz, which may be styled orthophyres. These aberrant types are found near the boundary of the area affected by the group, especially about Elgol and in parts of Scalpa.

BASIC DYKES.

One of the most noteworthy features of this area is the great profusion of basic dykes which traverse alike the pre-Tertiary strata and the volcanic and plutonic formations. They belong undoubtedly to numerous distinct groups of different ages, although the precise epochs cannot be in every case ascertained. Some of the dykes are cut off and metamorphosed by the granite, or portions of them are enclosed in that rock, as seen near Kilchrist old manse and Torran ; and it is probable that these early dykes represent the feeders of the basaltic lavas. The majority, however, are of later age, and, while some of them may possibly have served as feeders to the great group of dolerite sills, they are in general to be regarded as independent minor intrusions.

The dykes are not evenly distributed over the area included in the map. They are more abundant in the western portion, viz. in the

tract centring in the principal plutonic intrusions of the same suite. Further, they often shew a predilection for certain formations as country-rock. They are more numerous in the Jurassic strata and in the Cambrian limestones than in the Torridonian sandstones. They are very frequent in the gabbro of the Blath-bheinn range and in the basalt of Ben Lee etc.; but the granite of the Red Hills is intersected by comparatively few, and those mostly of a special type not met with elsewhere.

With the partial exception of the gabbro district, a very general parallelism is observable in the basic dykes of the area, the usual direction being between N.W. to S.E. and N.N.W. to S.S.E. A few follow quite other directions, and in some cases it can be verified that these have been guided by small faults or lines of crushing. The width of the dykes is usually only a few feet, but certain individual instances show more considerable dimensions. A large dyke intersecting the granite of Beinn na Caillich is a conspicuous object from Broadford. Sometimes, as in parts of the Strathaird peninsula, several dykes have been intruded successively in the same fissure, producing a multiple dyke; and occasionally more felspathic or acid dykes are in the same manner associated with basic, as may be observed near Elgol.

Petrographically the basic dykes exhibit some range of variety, both in texture and in mineral composition. The larger ones commonly have the coarser texture. Olivine may be present or absent. Certain groups of dykes are conspicuously porphyritic. The type already mentioned as restricted to the Red Hills is often porphyritic, with crystals of olivine, felspar, and augite. Certain basic dykes of limited distribution have a peculiar composition, the dominant felspar being oligoclase with some orthoclase. These rocks, unlike the ordinary basalts, have a tendency to assume the glassy form.

BASIC DYKES AND SHEETS PECULIAR TO THE GABBRO MOUNTAINS.

While some of the basic dykes already described occur plentifully in the gabbro of the Blath-bheinn range etc., we find there in addition minor basic intrusions which are confined to the gabbro tract and a narrow belt bordering it. These have the form partly of dykes, partly of sheets. The dykes do not differ petrographically from others having a wider distribution in the area, but they depart from the normal bearing of these in a manner which is probably significant. Many of them show a roughly radiate arrangement about the centre of the whole gabbro laccolite, while there is also some indication of another set at right angles to the radial ones.

More remarkable are the "inclined sheets" of dolerite and basalt, which are extraordinarily numerous in many parts of the gabbro mountains, imparting a stratified appearance to the slopes. They are inclined at angles less than 45° to the horizontal. Preserving a close parallelism at any one locality, they shew, when mapped out, a very evident law of arrangement. On Sgùrr na Stri they dip north; but, as we pass to Blath-bheinn and Garbh Bheinn, the dip changes to north-west and then west. Taking into account the Cuillin district on the adjoining sheet of the map, we find that the

dip is always inwards, towards the centre of the gabbro laccolite. Although closely connected with the gabbro as regards areal distribution, these sheets are of much later date ; for they cut through most of the basic dykes by which the plutonic rock is intersected. The feeders of these inclined sheets are probably to be sought among the radial dykes.

PERIDOTITE DYKES ETC.

About Ben Meabost and Ben Cleat, in the Strathaird peninsula, occur a few rather large dykes of picrite and peridotite. They are outlying members of a group of ultrabasic dykes developed in the Cuillins, where they are proved to belong to the very latest epoch of igneous activity in that district. The rocks have a rusty, weathered crust with a highly irregular surface, due to a peculiar heterogeneous constitution, lumps of olivine-anorthite-rock and peridotite, for example, being mingled in a matrix of picrite.

Two other ultrabasic, or partly ultrabasic, intrusions may be mentioned, the precise age of which is not determinable. Both have an irregular habit, partly dyke-like and partly sheet-like ; and both are of variable composition, ranging from a true peridotite to a rock with the characters of a gabbro. One of these occurrences is near the summit of Glamaig, intruded among the basalt lavas ; and the other is conspicuous on the face of Càrn Dearg towards Loch Eishort, where it intersects the Lias.

PITCHSTONE DYKES.

Acid rocks of glassy habit are found only sparingly in this area. They belong to a very late epoch, long posterior to the other acid intrusions noticed above. Examples occur on the north-west slope of Glamaig, on the east side of Glas Bheinn Mhòr, and on Beinn na Caillich, all in the granitic tract and situated nearly along a N.W. to S.E. line. In addition there are dykes which probably represent devitrified pitchstones. A group of these, with spherulitic structures, occurs in the neighbourhood of Coire-chatachan, on the east side of Beinn na Caillich.

METAMORPHISM PRODUCED BY THE TERTIARY INTRUSIONS.

The plutonic intrusions in the western portion of the sheet were of sufficient magnitude to give rise to considerable thermal metamorphism in the adjacent rocks, and both gabbro and granite are accordingly bordered by a belt of variable width, within which mineralogical transformations of this kind have been set up. The nature of the changes experienced by the rocks metamorphosed, and in some degree the distance to which the effects have been felt, are dependent on the lithological character of the rocks themselves.

The Torridonian strata which come in contact with the gabbro west of Broadford, and with the granite on Creag Strollamus, are quartzose sandstones not susceptible of any complex mineralogical changes ; but they are in places converted into quartzites. At the actual contact there has been in places a certain permeation of the rock by

the igneous magma, with resulting reactions on a minute scale, but this action has been strictly local. A like effect is to be observed near An t-Srôn, in the neighbourhood of Camasunary, where the felspathic and pebbly grits have been invaded both by the gabbro of Blath-bheinn and by certain irregular sheets of granophyre. The grits here have lost their usual red tint, and this is found to be an invariable incident of metamorphism.

Of special interest is the metamorphism of the dolomitised limestones of the Cambrian near the gabbro to the north-west of Broadford and the granite of Beinn an Dubhaich. In these cases mineralogical changes have been produced to considerable distances from the intrusions, while nearer to the contact, and especially in the patches of rocks enveloped in the intrusions, a high grade of metamorphism is constantly found. Being principally cherty dolomite-rocks prior to the intrusion, the rocks have given rise especially to silicates rich in magnesia and lime, viz. forsterite, tremolite, diopside etc. Magnesian silicates have been formed in preference to those of lime; and, as the available silica has not usually been sufficient to decompose the whole of the carbonate, calcite is left in the form of a recrystallised saccharoid aggregate enclosing magnesian silicates and other minerals. A forsterite-marble is a well-marked type, and by a further change of the silicate this often gives place to a serpentinous marble or ophicalcite. In the Beinn an Dubhaich limestone, in which the chert was partly distributed in accordance with the concentric ring forms, the serpentine follows a like arrangement; and, as Professors King and Rowney have shown, these ophicalcites reproduce in all its essentials the so-called eozoonal structure.* Another well-marked type is a pure white fine-grained marble, which is found to correspond with the pencatite and predazzite of the Tirol. This has been formed by the de-dolomitisation of a dolomitic rock free from chert. The magnesia was doubtless set free as periclase, but is now represented by the hydrate brucite, forming a granular aggregate with the residual calcite.

The various members of the Jurassic series do not in many places come within the belt which shows the maximum effects of thermal metamorphism. The quartzose grits which underlie the granophyre of Glas Bheinn Bheag, near Strollamus, are but little altered. On the slopes of Blath-bheinn above Abhuinn nan Leac we find, however, a noteworthy degree of metamorphism; and this is true, also, of the strata which adjoin the irregular sheets of granite on the east side of Blath-bheinn and Belig. Here a sandstone may be locally converted to a quartzite, while there has been an abundant production of brown mica in the shaly beds, with other transformations of the customary kind.

More worthy of special notice is the metamorphism of the basaltic lavas, as seen at numerous places, especially on Creagan Dubha, north of Beinn Dearg Mhòr, on Beinn na Crò, on Glamaig, and on the borders of the gabbro of the Blath-bheinn range. As seen in the field, the rocks assume a rougher aspect, and make more prominent features than their non-metamorphosed equivalents. They have also a darker colour, and thin slices show that the augite of the basalt has been partly

* "On the so-called Eozoonal Rock," *Quart. Journ. Geol. Soc.*, 1866, vol. xxii. p. 185.

or wholly transformed to hornblende. The amygdales of these metamorphosed lavas are found to contain, in addition to epidote and sometimes hornblende, various lime-soda-felspars, which have been formed at the expense of the lime-soda-zeolites so common in the amygdaloidal basalts of this group.

Where dolerite dykes have been metamorphosed by the plutonic intrusions, they show the same uralitisation of the augite and, in the more advanced stages of metamorphism, recrystallisation of the felspars and iron-ores. These effects may be verified in the portions of pre-plutonic dykes entangled in several localities in the granite of Beinn an Dubhaich, between Kilchrist and Torran.

The minor intrusions in the form of dykes and sills have not given rise to metamorphism comparable in degree with that produced by the large plutonic masses. In most places their effects are limited to unimportant changes, such as the discharge of the red colour from the Torridonian and Triassic strata, and this only in the immediate vicinity of the dyke. More radical transformations have been produced in a few places, where dykes were extremely numerous and the rocks traversed were of a kind peculiarly susceptible to thermal metamorphism. One locality is on the eastern shore of Loch Scavaig, about 700 or 800 yds. from Camasunary. Here the earthy limestones of the Oolites have developed large aggregates of lime-bearing silicates, especially nodules composed of large well-shaped crystals of diopside.

A. H.

INTRUSIONS ON THE MAINLAND AND ON CROWLIN ISLANDS.

On the mainland south of Loch Alsh the Tertiary igneous rocks are chiefly represented by basaltic dykes with the usual north-west or N.N.W. direction, but we find also a few dykes, with much the same strike as the above, which may be classed with the trachytes or trachy-andesites, and two small bosses of much decomposed gabbro, one about half a mile and the other four miles S.S.W. of Glenelg. The basaltic dykes are rare in the northern part of the area, but in the southern part as many as six or seven are sometimes seen in the breadth of a mile : a few thin basaltic sheets have also been noticed, among which we may specially mention one, with a southerly inclination, which outcrops in a nearly east and west direction on the south-east side of Barrisdale Bay.

Two dykes referred to trachyte or trachy-andesite, are seen about 30 yds. apart, on the coast a quarter of a mile south of Rudha na h' Airde Beithe. The southerly dyke, 6 or 7 ft. wide, is within a dyke of dolerite : it is edged on one side with a thin glassy selvage, and a little further in is characterised, as usual, by spherulitic structures in rows. The two dykes can be traced nearly to the road, and further south-east we find a dyke of similar composition which is well exposed in a streamlet about 60 yds. outh of Allt Mòr Shantaig, half a mile east of the road, and which can be traced with various interruptions to the north side of Loch Hourn, 300 yds. north-west of Eilean Rarsaidh : in the streamlet referred to, it sends squirts into a dolerite dyke which lies close to the south-west side. In the Eilean a' Phiobare, two and a half miles further south-west, a similar dyke, as much as 18 ft. wide, is again seen.

C. T. C.

In the Crowlin Islands, about six miles north-west of Kyle Akin, a number of dykes of olivine-basalt traverse the Torridon Sandstone in a general N.N.E. and S.S.W. direction. Though comparatively narrow—not exceeding 10 ft. in width—they usually discolour and indurate the Torridon arkoses for a foot or more from their margin. Immediately to the north of the limits of this map, one of these intrusions cuts a felsitic dyke trending in an east and west direction.

On the mainland north of Loch Alsh, some thin dykes of olivine-basalt traverse in an east and west direction the thrust Lewisian Gneiss and granulitic schists of the Moine series, and they also intersect the low plateau of Torridon rocks immediately to the south of Duirinish. An interesting example of a thin basalt dyke merging into a thin sill of the same material, is to be found about half a mile S.S.E. of that township. Still further south, and about a mile E.S.E. of Erbusaig on the hill named Garbh-ling, a thin sill of basalt has been traced for a quarter of a mile in the Torridon Sandstone.

B. N. P., J. H.

INTRUSIONS IN RAASAY.

The elevated tract of Suisnish Hill, which rises to 460 ft. in the southern part of Raasay, is formed of granophyre. The bedded masses of this rock partake of the general north-westerly strike of the Secondary rocks, and the white crusts of the volcanic rock render it somewhat similar in aspect to the white sandstones of the Oolitic series.

Numerous basalt dykes, and some dykes of granophyre, penetrate the Jurassic and older rocks, rarely appearing along planes of faulting and producing little apparent alteration in the strata.

H. B. W.

CHAPTER XIII.

FAULTS.

Mainland South of Loch Alsh.

In this chapter only a few of the more important and interesting faults will be described. The most important post-Cambrian thrusts have been already described in Chapter VI.

The most important group of faults on the mainland south of Loch Alsh strikes north-east or E.N.E. through the pass between Beinn a' Chapuill and Ben Sgriol, and thence to Strathchomair and Torr-Beag. This set, which may be named after Ben Sgriol, must keep under the Sound of Sleat in a south-westerly direction as far as the southern margin of the map. North-easterly it has been traced two miles beyond the eastern margin—as far as the survey has yet proceeded—and in all probability continues into the important dislocation, thirty miles further away, which defines Gleann Chaorainn and part of the valley of the Meig.* The strike is thus nearly parallel to the great fault along the Caledonian Glen. The effect of these Ben Sgriol faults is to bring the Moine schists of Ben Sgriol against the Lewisian Gneiss rocks on their north-west side for a distance of a mile and a half. Near Loch na h' Oidhche, the Moine rocks of the eastern part of Beinn a' Chapuill on the north-west side of the fault come near those of Ben Sgriol on the south-east, and it is noticed that, while the former are in a highly altered state, being thoroughly permeated by pegmatitic material, the latter are much less altered and contain very few pegmatites; so that it seems probable that the faults have either a considerable downthrow to the south-east, or else a large lateral shift which has moved the rocks in such a way that those which lie on the south-east side now lie a considerable distance north-east of those with which they correspond on the north-west side. The inclination of the more important lines of crush is south-east, but some of the branches incline north-west. A marked deviation from the general N.N.E. into a nearly east and west strike is found on either side of these disturbances, and may perhaps be explained as the result of twisting near lateral thrusts. The east and west strike is unusually well seen in the Gleann Beag of Glenelg, where, for a distance of at least three miles, it affects both the Moine rocks and the Lewisian Gneiss series and the isoclinal folds: one of the isoclines on the north side of Gleann Beag can be traced through the bend into the east and west strike, and it is seen that the limb which is the undermost when the strike is nearly north and south, becomes the uppermost when the strike is east and west. On the coast of Loch Hourn a dyke of lampro-

* *Summary of Progress* for 1904, p. 79.

phyre, and another which seems to belong to the vogesites, are both crushed near these disturbances, but the latter dyke is less affected than the Moine schist at its side, and so it seems possible that part of the movement is earlier than the vogesites. In a burn a quarter of a mile south-west of Bealachasain (one-inch map 72) a thin squirt of basalt, probably of Tertiary age, is seen within the main crush and is itself quite uncrushed, so that all the movements in this locality are probably pre-Tertiary.

Between Strathchomair and Suardalan, the watershed between the Glenmore and the Gleann Beag of Glenelg is very low, being along the line of these Ben Sgriol faults and crush breccias, which always form a belt of comparatively weak and readily eroded rock. Most of the water which goes down the Glean Beag—in a nearly west direction —comes down to Strathchomair in a north-easterly direction—also nearly along the Ben Sgriol faults—there being near Strathchomair a sharp bend, from north-east to west, at the point where the main drainage leaves the direction of these faults. It seems possible that at one time the water from the upper part of the Glenmore, above Bealachasain, may have flowed past Suardalan and over the low watershed referred to into Gleann Beag; but there is no clear evidence that it did so, and the rocks of the Glenelg-Ràtagain complex, which occupy so much of Glenmore just below Bealochasain, would probably be very readily eroded, after they were once exposed by the denudation of the overlying schists.

Another nearly parallel set of faults runs four or five miles north-west of the Ben Sgriol faults, and can be traced between Glenelg Bay and the neighbourhood of Totaig, often giving rise to conspicuous features in the landscape. The chief fault near Bernera shifts some of the outcrops more than half a mile and inclines south-east.

C. T. C.

Mainland North of Loch Alsh.

In the tract north of Loch Alsh only one dislocation of any importance is to be found. It runs in an east-west direction about a mile and a half to the north of Kirkton of Lochalsh, where it truncates the narrow belt of siliceous Moine schists in Coire Buidhe and traverses the thrust Lewisian Gneiss to the west, as shown on the map.

B. N. P.

Skye and Scalpa.

One of the most important of the dislocations which strike north-west is the fault which brings up on its south-west side the major thrust-planes of Sgiath-bheinn an Uird and Sgiath-bheinn Tokavaig (Chap. VI.). The crush breccias belonging to it are well seen in the burn above Camascross, and in a straight reach near the head of Allt Duisdale. On the north-west side of Loch Eishort, the displacement of the base of the Trias conglomerate is more than half a mile and the downthrow probably more than 500 ft. The strike is nearly parallel to that of most of the Tertiary dykes, a good number of which can be traced close along it for considerable distances; they are not appreciably crushed, and appear to have been intruded subsequently to

most of the fault movements. In the district generally, also, instances of Tertiary dykes in a crushed state are uncommon. About a mile slightly west of north of Kinloch, a dyke striking slightly west of north is partly crushed in a line parallel to its side : the dyke is in a line of fault with a considerable downthrow to the east, and, in view of its somewhat unusual direction, it appears probable that prior to the intrusion of the dyke there was along this line a crush-band of which the dyke took advantage. Some of the faults which strike north-east are also later than some of the Tertiary dykes : thus, rather more than three-quarters of a mile north-east of Kinloch, a fault with this direction breaks through a north-west dyke and displaces it slightly, though in another place another dyke is seen in the same fault in an uncrushed state. C. T. C.

A north and south fault, throwing down to the east, runs along Strath Suardal, and its scarp-face is well seen for some distance close to the roadside. Followed southward, it passes into a sharp monoclinal fold across the core of the limestone anticline, and then again into a fault running near the Boreraig footpath down the valley of Allt na Pairte. On the west side of this valley are several small parallel faults with like downthrow. The fault which for some distance makes the southern boundary of the limestone of the Beinn an Dubhaich anticline, is presumably related to elevation along this axis.

When the Strath Suardal fault is followed northward to the high-road, near the first milestone from Broadford, it is found to curve away to north-west or W.N.W., running for some distance along the shore, where it throws down the Lias against the older rocks and the Tertiary intrusions. It seems thus to correspond with a relative elevation of the plutonic centre of the eastern Red Hills. The south-east border of the granite *massif* of these hills is in places itself a line of displacement in the same direction. The north-west boundary is a straight fault throwing down to the north-west, *i.e.* still away from the granite. This fault has a considerable downthrow in its middle course, where it passes Creagan Dubha, but dies out in both directions. To this fault is due the preservation of the outlying area of basaltic lavas in this neighbourhood.

A number of faults traverse the Torridonian rocks of Scalpa, the most important one running south-east from Camas na Geadaig with downthrow to the north-east. In the south of the island the subsidence of a faulted block has preserved a patch of the Tertiary basalts with the Cretaceous rocks beneath, while in the south-eastern corner a curved fault lets down the Jurassic strata of Scalpa House.

Other faults, affecting the Tertiary igneous rocks in the western portion of the map, are usually of small throw. Several are mapped at the southern end of the Blath-bheinn ridge. It is probable that, where no pre-Tertiary strata are present to furnish a guide, faults in the igneous rocks have sometimes escaped detection. A. H.

A great dislocation, already referred to as the Camasunary fault, runs N.N.E. from Camas Fhionnairidh along the valley of Abhuinn nan Leac.* On the shore of that bay springs issue from a narrow gap, where the cliff of Great Estuarine strata gives place to a low-lying tract of Torridon sandstone. On the latter the base of the Lias rests in a small exposure north of the bay and little above sea-level.

* *Summary of Progress* for 1901, *Mem. Geol. Survey*, 1902, p. 147.

As the Camasunary fault cuts out the whole Jurassic sequence up to the higher part of the Great Estuarine series, its easterly downthrow must exceed 2000 ft. Its age can be fixed closely. Upper Oxford Clay here, as everywhere on either side of this fault-line, follows the estuarine strata, thrown against Torridonian and Lower Lias. Hence the fault is evidently later than the Oxford Clay. On the other hand, east of its line throughout Strathaird the Tertiary volcanic rocks succeed Upper Cretaceous or Oxford Clay, or just overstep on to the Great Estuarine series in the north of the promontory. But immediately west of the fault these volcanic rocks lie on the basement beds of the Lias or even on the Torridonian. Hence the dislocation is clearly earlier than the Tertiary volcanics. Again, wherever Upper Cretaceous strata occur in the neighbourhood of this fault-line, they rest upon Oxford Clay on the east side of it, but on the lowest Lias in their only known exposure west of it (see p. 133). There is then a reasonable presumption that the Camasunary fault preceded the Upper Cretaceous.

Other pre-Tertiary faults with easterly downthrow have been detected in neighbouring districts.*

The Camasunary fault has an important bearing on the distribution of the Jurassic and older rocks. Later movements have not obscured the prevalent westerly dip,† and this fault terminates the general upward succession westward from the east of Strath. It brings up again the lowest members, and the same sequence recurs on the west. Moreover, a prolongation of its line produces a similar effect for a long distance southward (see Fig. 2) as well as northward.

A direct continuation southward would pass between Eigg and Muck on the east and Rum on the west. Now at Laig Bay on the west coast of Eigg, Cretaceous strata overlie Oxford Clay at sea-level, and it appears that, wherever the Jurassic rocks are known in the West of Scotland, they exhibit no interruption of their usual sequence, while overlapping of the oldest Secondary beds never extends far above the Trias. Hence it must be assumed that some 2000 ft. of Mesozoic strata are present below sea-level at Laig Bay, and that the surface of the Torridonian is at least as deep down. But in Rum Mr. Harker finds Torridon sandstone underlying the Tertiary basalts at roughly about 600 ft. O.D. He states also that the base of the Tertiary volcanic series varies in Eigg from below sea-level in the south to about 1000 ft. O.D., so that these rocks are not displaced as the result of any great single dislocation between Eigg and Rum. The Secondary rocks of Eigg afford then a strong basis for the belief that the pre-Tertiary Camasunary fault may pass between these islands.

Northward, it might be expected that this fault would traverse the north-west corner of Scalpa, between the Oxfordian and Cretaceous strata of Mullach nan Carn, which lie at an altitude of 1000 ft. or more, and the Trias of the south-east shore of Caol Mòr. But Mr. Harker detected no evidence of any such fault crossing the Torridonian rocks.

Of dislocations later than the Tertiary volcanic rocks, two or three westerly or north-westerly faults intersect this earlier one near

* See A. Harker, "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, p. 413, and C. T. Clough, "The Geology of West-Central Skye, with Soay," *Mem. Geol. Survey*, 1904, p. 5.

† A. Harker, "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, p. 413.

covered tract north of Strathaird is mainly conjectural.

Numerous small north-westerly faults with north-easterly downthrow, disturb the Mesozoic rocks that extend across Strath. West of Boreraig a sill capping an escarpment in the Lower Lias is displaced by little faults eight times in half a mile, and illustrates the difficulty of estimating the thickness of homogeneous rocks in which such faults could not be traced. C. B. W.

CHAPTER XIV.

GLACIATION AND GLACIAL DEPOSITS.

Area South of Broadford and Loch Alsh.

ICE-FLOW AND ERRATICS.

On the mainland south of Loch Alsh the general direction of the ice-flow appears to have been nearly from east to west, as is shown by the glacial striations and the westerly carry of many boulders, for example, those of the broad diorite dyke which passes half a mile north of Rarsaidh (Loch Hourn), and those of limestone, belonging to the Lewisian Gneiss series, which are scattered on the eastern slope of Beinn Bhuidhe (Kylerhea, Skye). The direction may, however, vary locally to a great extent, and no doubt changed in many districts as the ice-sheet dwindled and the pressure from the east became less, so as to allow the ice from certain hills and corries to proceed down the nearest slope, even if this were in a somewhat easterly direction. The numerous striæ in the Coire Dubh, on the north-east side of Ben Sgriol, which strike north-east along the floor of the corrie, are certainly due to ice flowing from the south-west, for otherwise boulders belonging to the Glenelg-Ràtagain complex, such as are common near Loch Iain Mhic Aonghais, would have been seen in the corrie. The depression, striking north-east, in which this loch lies and which crosses an unusually low part of the watershed between the Glen Beag and Glenmore of Glenelg, was probably at one time occupied by ice coming partly from the south-west and partly from the north-east, and it has been so deepened that the valleys on the south-east side—Gleann Aoidh-dailean and the glen on the north-east side of this—are now left as "hanging valleys," the erosion along their lower portions having been very little since the deepening of the depression referred to.

Ladhar Bheinn, 3343 ft., a hill only a mile within the adjoining one-inch map 61, was perhaps never completely overridden by ice from the east. On its upper crests, above 2800 or 2900 ft., we lose the rounded glaciated forms which are so general at lower elevations, and no boulders of pegmatite veins, nor of siliceous Moine schists like those *in situ* over a large area further east, have been noticed near the top. A deposit consisting chiefly of angular slabs of rock like those *in situ*, which belong to a pelitic gneiss series, spreads, however, over a considerable area west and south of the hill top and reaches almost to the highest point. Near the top of Beinn na Caillich, 2523 ft., on the south side of Loch Hourn, the drift is also of a local character and chiefly composed of slabs of siliceous schist, no pieces of the Ladhar Beinn rocks being found, though they compose a great tract only two miles to the east and south-east.

That the pressure of ice from the region further east was, however, at one time very great, is well shown by the striæ striking west and south-west which are found a little distance within the adjoining one-inch map 72, on the watershed on the east side of the head of Glenmore, on heights exceeding 2500 ft., and by the granitic boulders which have been carried over this watershed near Bealachasain. It is remarkable, indeed, how scarce these boulders are on the hill slopes adjoining the lower part of Loch Duich, the great majority having apparently been carried westward into Glenmore.

It seems probable that some of the variations in direction may be due to an " undertow " going along some of the deeper valleys, while the higher portions of the ice-sheet proceeded in a general easterly direction. The south-west striæ on certain of the lower slopes on the sides of the Sound of Sleat and of Kyle Rhea may belong to this class. Some of these, for example, those a quarter of a mile north-east of Knock, occur in localities far away from any morainic drift.

There can be no doubt that all the south-eastern peninsula of Skye was overridden by ice from the mainland at the period of maximum glaciation, for very little below the top of the highest hill, Sgùrr na Coinnich (2411 ft.), slabs of Moine schist are tolerably common.

In most of this peninsula of Skye, the striæ run nearly north-west or even N.N.W., as may be seen near the tops of Beinn na Caillich, Sgùrr na Coinnich and Beinn na Seamraig, and in the low tract extending between Loch na Dal and Broadford Bay, the ice having been generally compelled to flow north-west so as to get round the northern side of the Red Hills. Indeed, on the top and eastern side of Ben Suardal the flow seems even to have been N.N.E., approximately parallel to the steep slope of Beinn na Caillich (Broadford), which lies but a little distance further west.

Further south, near Ord, Tarskavaig and the southern margin of the map, the most common direction is nearly west, and the portion of ice which passed over this tract probably passed on the south side of the Cuillin Hills. That there was a movement from the east over Sgiath-bheinn an Uird is shown by the numerous boulders of red Applecross grit which are found scattered over this almost snow-white quartzite hill. Further south, near Tarskavaig, a similar westerly movement is proved by the boulders of gneiss with long prisms of actinolite of just the type so common near Knock. But between Sgiath-bheinn an Uird and Tarskavaig, ice from the west or north-west must at one time have extended up Glen Ord for some distance, for it has left behind it a boulder clay containing, besides pieces of the Lewisian gneiss from the east, others of Mesozoic rocks and of marble, which has a close resemblance to the altered Durness limestone found in Strath. The boulder clay is well exposed on the south side of the river rather more than half a mile above the foot of the burn, and is in parts of a dark grey colour, which is somewhat unusual in this district, and may perhaps be due to ground-up Liassic shales.

BOULDER CLAY.

In the mainland south of Loch Alsh, boulder clay covers considerable spreads, particularly in the lower parts of the valleys, but also occasionally in the higher tracts near the western margin of the map,

for example, near the head of Gleann Aoidhdailean, where its smooth even slopes form a striking contrast to the adjacent hummocky moraines. It is generally either of a brown, pale grey or greenish grey colour, but the latter tints change into yellow or brown near weathered surfaces, and at the same time the texture becomes looser and more sandy. Occasionally the boundary between a morainic drift and an underlying boulder clay is well defined by the character of the surface and by a line of springs or wet ground between the two, but in most localities we can see no sharp boundary, and we have not therefore ventured to draw one on the map.

In the part of the south-eastern peninsula of Skye which lies north-east of Loch na Dal and the head of Loch Eishort, there are considerable tracts of boulder clay, in close association with others of morainic drift. But in the part on the south-west side, it is remarkable how little drift, which is in this part composed entirely of boulder clay, has been left behind, though the glaciation has been very intense.

MORAINIC DRIFT.

On the mainland south of Loch Alsh morainic drift is very widespread, but moraines in crescentic forms, or in long ridges with a clear relation to the form of the ground, are uncommon. It is probable that ice still filled part of the Glenmore, and also most of Loch Hourn and Loch Duich, whilst the 100-feet raised beach was being formed, for this beach cannot be traced so much as three miles up either of these glens nor up the lochs referred to. A long tongue of ice probably occupied the central part of Glenmore as far down as Bealary, whilst the sea filled the lower part of the valley, and perhaps also narrow spaces extending some distance up on either side of the ice-tongue : the position of part of the ice-tongue is now represented by morainic gravel mounds, the tops of which are lower than the upper surface of gravel terraces on either side, which pass gradually down into the 100-feet raised beach.

In the south-eastern peninsula of Skye a hummocky morainic drift is the prevalent type in Glen Arrochs and Kylerhea Glen, and is common also further north-east; but it is not found anywhere south-west of An Sgulan and Beinn na Seamraig, so that the hills in this lower area do not seem to have been sufficiently high to have nursed local glaciers at any time after the great ice-sheet had melted away. In Kylerhea Glen moraines are well developed close on the west and south sides of the 100-feet beach, and were no doubt formed by a glacier coming down the glen in an easterly direction.

FLUVIO-GLACIAL DEPOSITS AND GLACIAL LAKES.

In certain localities we find beds of evenly stratified clay, fine sand and gravel, which appear to have been deposited in quiet waters of considerable depth, but which are far from any loch or considerable stream, and in positions in which no great sheet of water can have been recently kept up, unless the shape of the ground has altered to a much greater extent than we suppose, or unless barriers of ice existed in one or more directions to prevent the free escape of water. The last expla-

nation, which has recently been so fully presented by Messrs. Kendall and Muff for the Cheviot Hills,* and by the former author for the Cleveland Hills,† affords no doubt the correct solution of the difficulty.

The site of one of the most interesting of these old glacier-dammed lochs lies close to and north-east of Strathchomair, in the low watershed between the Gleann Beag and Glenmore of Glenelg, at a height of about 500 ft., and it is shown on the accompanying sketch map (Fig. 13). The deposits collected in it have been deeply eroded by later

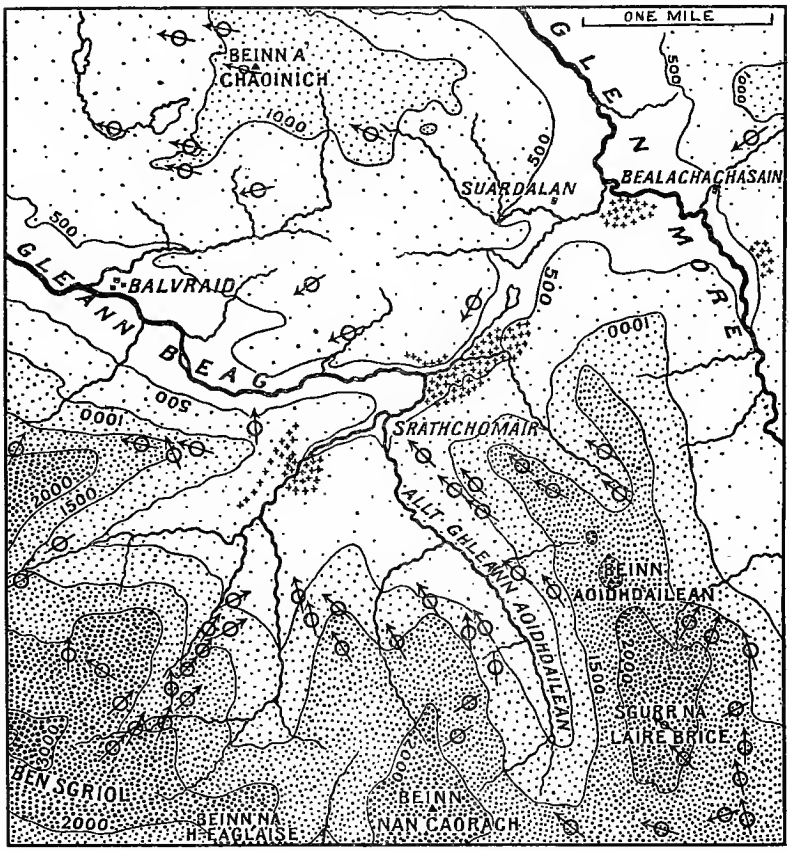


FIG. 13.—Map to show the Fluvio-glacial Deposits near Strathchomair. Scale: 1 inch = 1 mile. The fluvio-glacial deposits are shown by small close crosses. Contour lines are drawn at intervals of 500 ft. above sea-level, and the more elevated areas are shown by closer stippled patterns than the lower. Arrows passing through circles indicate glacial striations, and the probable direction of ice-flow. Straight lines passing through circles indicate glacial striations in places where the direction of ice-flow is uncertain.

streams and are well exposed in a section nearly 600 yds. north-east of Strathchomair, where they are free from large stones and at least 50 ft. thick. The lower part, about 30 ft. thick, consists of well

* "Evidences of Ancient Glacier-dammed Lakes in the Cheviots," *Rep. Brit. Assoc.*, 1901, p. 646.

† "A System of Glacier Lakes in the Cleveland Hills," *Quart. Journ. Geol. Soc.*, 1902, vol. lviii. p. 471.

stratified clay and sand, while the upper 20 ft. includes beds of gravel also : the lamination is nearly horizontal, but near the base a flattened fold was observed which may have been the result of pressure from the south-west. These deposits extend at least half a mile in a south-west and north-east direction, and the old lake was probably somewhat longer and about a quarter of a mile wide ; for a little north of, and about 40 ft. higher than, the adjacent sharp bend in the Gleann Beag burn, we find remains of an old nearly horizontal gravel terrace,* which was perhaps formed within the loch close to its margin. The loch was probably dammed up by ice-barriers on two sides, one on the north-east formed by ice advancing south-west from the head of Loch Duich, and another on the south-west formed by ice descending from Ben Sgriol and perhaps also from Beinn na h' Eaglaise and Beinn nan Caorach. The fine deposits occupying most of the site are covered by coarser materials with a hummocky surface and with some large boulders, and it seems probable that these latter have been left by ice which advanced further and covered the site of the loch.

Other glacier-dammed lochs, the sites of which are partially indicated by gravel terraces at different elevations, the highest about 800 ft., appear also to have existed in the valley about a mile W.S.W. of the above,† and were perhaps formed at a time when the ice from the north-east was more advanced and that from Ben Sgriol less so.

In the Croulin Valley, on the south side of the mouth of Loch Hourn, several stratified deposits have been observed which are probably of Glacial age. One of these forms a nearly horizontal terrace, or series of minor terraces, between the 300-feet and 400-feet contours, and was probably deposited in water dammed back by a big glacier which filled Loch Hourn and reached some distance up the adjoining mountains.‡ A higher deposit of a more finely bedded character is found further up the same valley between the 800-feet and 900-feet contours, and is as much as 80 or 90 ft. thick. It is composed of bands of finely laminated stoneless clay and sand—at least nine in number—mixed with other bands which contain boulders and have a considerable resemblance to some boulder clays : the stratification is generally nearly horizontal, though some of the minor laminæ are contorted. The slope of this part of the valley is so steep that it seems necessary again to suppose that some ice-barrier crossed it a little below the deposit, so as to hold up the water in which it was formed. Perhaps such a barrier was provided by the ice going down Loch Hourn at a time when the conditions were more intensely glacial than when the lower deposit, between the 300-feet and 400-feet contours, was formed.

About 230 yds. S.S.W. of the Ordnance Station 956 on Sgùrr na h-Iolaire (the Sleat district of Skye), we find gravel beds mixed with thin peaty laminæ and almost horizontal, though the slope in which they rest is very steep. It is difficult to understand how these almost horizontal beds could have been formed, unless they were laid down in water of some depth, and in this case some barrier to hold the water

* D. Milne Home, " Fourth Report of the Boulder Committee," *Proc. Roy. Soc. Edin.*, 1878, vol. ix. p. 664, plate vii. fig. 7.

† D. Milne Home, *loc. cit.*

‡ A loose sandy deposit which slopes steeply with the stream, but is at a higher level than the terraces coloured as alluvium on the published map, may also be classed as fluvio-glacial.

back must also have been necessary. The general direction of flow of the great ice-sheet in this part of Skye was, as already stated, from east to west; and it seems not unlikely that the low ground which strikes east and west on the south side of the Sgùrr, was occupied by ice for some time after the Sgùrr itself was free. If this was so, the northern edge of this ice may have formed the barrier which seems required to explain the phenomena described. C. T. C.

The Red Hills, Blath-bheinn and Adjacent Tracts.

ICE-FLOW.

In the western half of this sheet the advance of the Scottish ice-sheet across Skye was arrested on encountering ice of local origin, and there is an area within which the glaciation was strictly local. This area includes the Red Hills and the Blath-bheinn range, which, with the Cuillins on the adjacent sheet to the west, gave rise to a small local ice-cap, which withstood the invasion from the mainland. On Skye itself the Scottish ice scarcely forced its way beyond Broadford and the lower part of Loch Eishort. To the north-west of Broadford the boundary between the native and the foreign ice is quite sharply defined, passing through the Kyle of Scalpa and the "Narrows" of Raasay. On the smaller islands boulders from the Scottish mainland occur up to all altitudes, while on Skye they are found only on the beaches. To the south of Broadford the line of demarcation is not quite so precise, owing to oscillations in which one or other of the opposing bodies of ice gained advantage for a time. Thus, along the Boreraig footpath, west of Loch Lonachan, boulders derived from the east are mingled with others from the Red Hills to the north-west; and a similar commingling is found further south. It is quite clear, however, that the Scottish ice swept round Central Skye to the south, just as it did to the north, giving rise to the westward-pointing striæ observed towards the extremity of the Strathaird peninsula.

The movement of the native ice among the Skye hills was generally in accordance with the form of the ground; but, during the maximum glaciation, the pressure of the Scottish ice made itself felt in the outskirts of the area, causing an increasing diversion westward. In the Red Hills the precise lines of flow are not always easily followed; for striæ are rarely preserved, and the dispersal of boulders gives little information in the absence of recognisable local rocks. Considerable ice-streams flowing down the Strollamus valley, Srath Mòr and Loch A'nort impinged point-blank on the flank of the Scottish ice-sheet, and were ponded back. The much larger contribution from the Sligachan valley was too powerful to be thus arrested, but (in the part contained in this sheet of the map) it was forced northward.

In the gabbro tract of the Blath-bheinn range the movement is easily followed, and, owing to the strong relief of the ground, has been somewhat sinuous. The ice, first moving off from the crest-line in the direction of the slope, has usually followed a course in agreement with the main valleys, only occasionally overriding some of the lower ridges. Thus, from Coire Uaigneich, to the east of Blath-bheinn, part of the ice overflowed into the head of the Kilmarie valley, while the remainder took a more circuitous line, following down the valley

until it met the contributions from the more northerly corries, and being then swept southward. Of the powerful body of ice which found its way southward along the valley of Kilmarie, part escaped to the sea near Kilmarie Lodge, only to be diverted south-westward across the peninsula. The remainder flowed directly south-westward into Loch Scavaig, to which the ice of Abhuinn nan Leac and the Camasunary valley also converged. The last-named valley carried the ice-drainage of a considerable tract of mountain ground. Having the Blath-bheinn range on the east, Sgùrr an Eidhne and Sgùrr na Stri on the west, and Ruadh Stac on the north, it also received, during the maximum glaciation, part of the ice from Harta Corrie, forced over Druim an Eidhne. The erosive power of the converging stream is partly indicated by the rock-basins of Loch an Athain and Loch na Creubhaich, the latter with a depth of 91 ft.

During the maximum glaciation the mountains of Central Skye were completely buried beneath a continuous ice-cap ; * but there succeeded a later glaciation confined to valley-glaciers, and during this stage the direction of flow was in some places modified. This is seen in the belt fringing the mountains, and the modification is simply a reversion to a natural radial outflow, no longer disturbed by the general westward diversion. This clearly indicates that the Scottish ice-sheet had ceased to press upon the coasts of Central Skye.

BOULDER CLAY ETC.

More or less continuous drift deposits overspread a large part of the lower ground about the Red Hills and the Blath-bheinn range ; but they do not often attain any considerable thickness, and sometimes fail entirely, especially in the granite country. The most noteworthy accumulations are found in some of the main valleys, but even here they only locally conceal the form of the rock-surface below. On the flanks of the mountains the drift deposits often extend to 1000 or 1250 ft. altitude, and send tongues up the glens to 1500 ft. or more. Among the outlying lower hills the line must usually be drawn lower down, and in places along the coast it sinks to sea-level.

The composition of the deposits varies in different parts of the area. The local element is commonly found to preponderate greatly among the boulders and, so far as can be ascertained, in the matrix too ; but the boulders include also, in diminishing proportion, rocks derived from higher ground along the lines of flow followed by the ice. The dependence of the material upon the local country-rocks is well seen in many parts of the granite hills, where what is elsewhere a clay becomes a sand. At a distance from the mountains the boulders are mostly of small size, with a few larger ones, and they are sometimes scattered rather sparingly through the matrix. In the mountain glens boulders of conspicuous size make up a much larger proportion of the deposits.

In parts of some of the valleys, and especially about the mouths of certain of the larger valleys draining the Red Hills, there occurs a type of accumulation which has been styled " hummocky drift " and " kettle moraine," presenting a very characteristic appearance.

* For a more detailed discussion, see Harker on " Ice-Erosion in the Cuillin Hills, Skye," *Trans. Roy. Soc. Edin.*, 1901, vol. xl. pp. 221–252.

The ground is closely studded with circular mounds, like tumuli, from 10 or 15 to 60 ft. in height, only rarely showing any linear or other arrangement. The appearance is very striking near Strollamus and Luib, where the ice-flow from the Red Hills abutted on the Scottish ice. Patches of hummocky drift are also seen from the head of Loch Ainort northward to Tormichaig, in Srath na Creitheach, and about the head of Loch Slapin. Their limit against the smoother areas of drift is in most places quite sharply defined.

MORAINES.

Well defined true moraines, as distinguished from the "kettle moraine," are not in general a noticeable feature in the Red Hills of Skye. The best examples are seen about the mouth of Coire Gorm, between Beinn na Caillich and Beinn Dearg Bheag. They are observed following the trend of the burn Allt Beinne Deirge, where it emerges from the corrie into the strath; and on the north side there is a well-preserved segment of a crescentic moraine transverse to the direction of outflow of the ice.

ERRATICS.

It has already been remarked that the portion of Skye west of Broadford Bay and Loch Eishort was glaciated only by ice from the local mountains. The erratics here are thus wholly of local rocks. Most prominent are boulders of granite, sometimes of large size and often numerous, as above Torran, near Coire-chatachan, in the Kinloch-Ainort valley etc. Other rocks figure conspicuously in their appropriate districts, as volcanic agglomerate in Coire Choinnich, and gabbro in the track of the ice shed from the Blath-bheinn ridge. Only at certain places on the coast-line do foreign boulders come in, the most easily recognised being banded gneisses of the "Moine" type. On Scalpa and Raasay, which were overridden by the ice-sheet from the Scottish mainland, these foreign erratics are found, though sparingly, at all altitudes.

LAKE-BASINS.

In Srath na Creitheach are two rock-basins, occupied by Loch an Athain and Loch na Creubhaich, of which the second and larger is nearly a mile in length and 91 ft. in depth.* Loch Kilchrist, in Strath Suardal, is also a rock-basin, though a very shallow one. The shallow tarns in Srath Mòr may be merely held in by the alluvial deposits.

A. H.

Strathaird.

ICE-FLOW.

Striæ occur on the sandstones of the eastern ledge, where their preservation on exposed surfaces of relatively low tracts may possibly be connected with recent diminution of the peaty covering. On the

* This sounding was kindly communicated by the proprietor, Mr. R. L. Thomson.

northern part of the sandstone ledge they tend to diverge radially down from An Càrnach between N. 72° E. and S.S.E. But some cross striæ on the lower slope mark the general southerly trend of the ice down Loch Slapin. Further south the direction becomes south-westerly with the curve of the high ground.

At Elgol the bare dip-slope of the steep escarpment made by the highest Inferior Oolite sandstone, inclined from 5° to 10° N.W., is remarkably glaciated. For nearly a mile its surface is covered with scratches and polished shallow grooves like "slides" on a frosted pavement. These vary in direction between S. 25° W. and S. 75° W., becoming rather more westerly towards the coast, as the ice followed the curve of the hill. The escarpment does not seem to have modified the direction of flow in the least. One of the grooves shows that the ice overrode it obliquely. Inequalities of surface, such as trenches produced by weathering dykes, are bevelled on the side facing N.E., but not on the opposite side.

BOULDER CLAY ETC.

Stony drift, thickly covering the head of Glen Scaladal, extends northward into the valley of Abhuinn Cille Mhairè. The upper part of this contains hummocky drift ending in a lobe which points down the valley. The low ground at the north end of Strathaird is thickly covered with drift, hummocky except in the middle of the tract. This type of drift occurs at intervals on the slopes all round the low ground on both sides of the main valley. C. B. W.

Raasay.

Boulder drift caps the low cliff to the south-east of Suisnish, Raasay. It is composed of fine and coarse débris, more or less rounded, and sand 6 ft. or more in thickness, and resting perhaps on boulder clay. The stones consist of Torridon sandstone, granophyre, masses of shale, etc., and they have a rough bedding, arching over seawards.*

Perched on the cliff at Rudha na Cloiche is a large boulder of Torridon sandstone, measuring roughly 9 ft. × 6 ft. × 6 ft.

Glacial striæ on the granophyre of Suisnish Hill (at about 380 ft.) indicate an ice-movement in a direction of N. 30° W.

To the east of Rudha na Cloiche there are fine cliffs of boulder clay with thin cappings of gravel, the boulder clay consisting of rough loamy clay with many stones and large boulders; the whole in places 30 or 40 ft. thick. Springs are thrown out above it. H. B. W.

Mainland North of Loch Alsh.

INTRODUCTION.

In this part of the mainland there is clear evidence of the intense glaciation to which the country was subjected, though it is rather difficult to define the precise limits of the later glaciers. But as no moraines have been recorded west of a line extending from Achmore

* The deposit may belong to a raised beach.—C. T. C.

in Srath Ascaig to Kirkton of Lochalsh, and as no traces of the 100-fe beach have been found east of that line, the inference may be draw that it roughly defines the limits of the later glaciation.

On the plateau of Lewisian Gneiss few striæ have been recorde but they are very numerous throughout the area occupied by th Torridonian rocks. They clearly show that the general movemer of the ice during the period of extreme glaciation was a few degre to the north of west, with slight local variations due to the form c the ground. Thus, in the neighbourhood of Plockton at the mout of Loch Carron, the ice-markings vary from W. to W. 15° N.; but o reaching the sea they bend round towards the south, and on Eilea Dubh Dhurinish, less than a mile from the shore, they run about W.S.W South of Duirinish this movement to the south of west is still indicate by the striæ, but beyond Erbusaig towards Kyleakin the evidenc shows that the ice on reaching the west coast was deflected and pr ceeded in a north-westerly direction. This trend is obvious in th islands near the Plock of Kyle. There can be little doubt that thes striæ belong to the period of maximum glaciation, when the ice move in a north-westerly direction between the mainland and Skye. I this connection reference may be made to the ice-markings on th Crowlin Islands, situated six miles west from Plockton, where th trend is N.N.W.

East of the road leading from Kirkton of Lochalsh to Stromeferry in the north-east corner of the map, the striæ indicate that the ice flow was determined by the features of the ground, as if they had bee produced at a time when lobes of ice were pushed further west alon the valleys than on the intervening high ground. Thus in Srat Ascaig the ice-markings seem to vary with the trend of the valley being at one point nearly north-west and at another nearly due west.

BOULDER CLAY.

The western part of the area is singularly free from boulder clay only small patches being found in the hollows between the glaciate surfaces of Torridon Sandstone. The deposit consists of a stiff gre clay with boulders locally derived and fragments of different member of the crystalline schists of the Moine series. Larger patches occur i the neighbourhood of Loch Lundie and Loch Achaidh na h-Athinnic S.S.E. of Plockton, and also in the bottoms of the valleys near Bal macara and Loch Alsh.

On the higher plateau it is sparsely distributed, and it also occur underneath morainic deposits and gravels in Srath Ascaig, Gleam Udalain, and the Balmacara Burn.

MORAINES.

A careful examination of the evidence within the area lying t the east of a line extending from Achmore in Srath Ascaig to Kirkto of Lochalsh, makes it clear that the glaciers which extended dow the main valleys were only lobes of the great confluent glaciers tha emanated from the Monar region, overtopped the passes, and fille the Ling depression (Sheet 72). Lateral moraines occur on th slopes north of Beinn Conchra at a height of 1000 ft., thus markin

the upper limit of the ice at one period of its development. This mass of ice, which must have reached a thickness of 1000 ft. at least, flowed down into Loch Alsh, and evidence of its retreat is to be found in the form of moraines on the promontories of Avernish and Ardelve.

Another lobe of ice passed down Gleann Udalain, whose floor is strewn with moraines in such a manner as to show that the ice flowed down into Loch Alsh and probably became confluent with the glaciers emanating from Loch Long and Loch Duich. The upper limit of the Gleann Udalain glacier during one of the stages in its development is indicated by long lateral moraines on the east side of Auchtertyre Hill, while a terrace that runs along the slope for a distance of 600 yds. may be due to deposition in a temporary lake along the ice margin, which drained over the col into Auchtertyre Burn. Similar moraines occur on the east side of this valley on the western declivity of Creag an Earbaill. The bottom of Gleann Udalain seems to have held a series of lakes ponded by moraines, now silted up by the stream.

The disposition of the moraine material in Gleann Udalain at a point where the stream flows due west about a mile to the north of Nostie Bridge, suggests that it there fills a pre-glacial hollow, whose continuation seawards is buried under drift. On the retreat of the ice, the river, by following the lowest levels on the surface of the drift, has been directed westwards for a third of a mile on to the old rocky side of the valley, in which case the gorge between this bend and Nostie Bridge is partly or wholly post-glacial.

A lobe of Gleann Udalain ice seems to have extended west between Beinn Raimh and Auchtertyre Hill, the terminal moraines of which can be traced at intervals for about two miles from a point three-quarters of a mile north of Auchtertyre Hill northwards by the west side of Loch an Smeoraich to the head of Gleannan Dorch.

Higher up Gleann Udalain another lobe of ice, issuing from the glacier that filled that valley, crossed the col north-east of Meall Ailean, and descended Srath Ascaig as far as Fernaig. The well-marked 100-feet raised beach that occurs there at the angle of Srath Ascaig and Loch Carron, only a small part of which comes into Sheet 71, was evidently laid down against the front of the glacier. The 100-feet beach at Achmore, shown on the map, indicates a shrinkage of the glacier for some distance above Fernaig, but its retreat proceeded so slowly as to permit the deposition of a barrier of marine sands and gravels across the valley. When the glacier vanished from Srath Ascaig a freshwater lake was formed in that valley, which was ponded back by the barrier of 100-feet beach materials at Achmore.

The sharp col of Bealach a' Choire between Gleann Udalain and Srath Ascaig may have been cut by the water escaping from the ice during its retreat. The small stream that now flows along the bottom of the pass takes its rise close to the edge of the alluvial plain of Gleann Udalain, hence it is probable that the cutting of the col must have kept pace with the shrinkage of the glacier. B. N. P., J. H.

CHAPTER XV.

RAISED BEACHES AND RECENT DEPOSITS.

Area South of Broadford Bay and Loch Alsh.

BEACHES.

The highest raised beach is that known as the 100-feet beach, but 100 ft. is a little less than the average height of the inner margin even in those localities which are far from river mouths; and up many of the glens the level gradually increases to 200 ft. or even more. The higher portions must represent old river terraces which merged into the beach; but no sharp line can be drawn between the two, and in the map the colour given to the beach has often been carried some distance up, over parts of the cotemporaneous river terrace.

The sands and gravels composing this beach are usually separable into two divisions, a lower one of somewhat fine material, which is very false-bedded and occasionally contorted, and an upper, composed of coarse gravel and boulders, which frequently cuts across the denuded edges of the lower beds.

On the mainland south of Loch Alsh, the 100-feet beach is well shown near Glenelg, Sandaig and Inverguseran, but it is not developed up Loch Duich nor Loch Hourn, nor far up the Glenmore and Glean Beag of Glenelg, owing probably to these lochs and the upper parts of these glens being filled with ice at the time the beach was being formed elsewhere.

In Skye the beach is perhaps best seen between Kyleakin and Broadford, where it is sometimes half a mile broad. It is also represented at Kylerhea, Isle Ornsay, Knock, Tarskavaig, Ord and many other places. At Kylerhea, moraines come down to its edge, and a local glacier, advancing down the glen, has perhaps partially interfered with its development.

The hamlets of Arnisdale and Carron (Loch Hourn) are built on a beach which attains a height of about 40 ft. on the open coast, and is in places distinctly separated from a lower raised beach. Near Tokavaig and Eilean Heast, and various other places, terraces occur of intermediate height between the 20-feet and the 100-feet raised beaches, and some of these may be classed with the higher one of Arnisdale. Others, however, reach almost to 100 ft. at their inner margins, and perhaps merely represent denuded portions of the 100-feet beach.

The 20-feet (or 25-feet) beach is represented at frequent intervals along the whole coast-line, but in many of the rocky more exposed parts it is in the form of a shelf or notch with little or no deposit. At

Bernera and the north side of Ellanreoch (Glenelg) the gravel in this beach is heaped up into storm-banks, and is evidently still frequently rearranged in winter-time. In the bed of Abhuinn Ceann-lochan (Loch na Dal), about 150 yds. above the foot of the burn, but only from 25 to 40 yds. above the highest point to which ordinary spring tides ascend, a muddy shell-bed was observed which probably belongs to the neighbouring 20-feet beach, or else to some other below the 100-feet. Mr. Thos. Scott, who kindly examined the materials collected from this bed, and has drawn up the List of Species inserted in the Appendix III., states that "with very few exceptions the species may be found living from the shore down to eight or ten fathoms. None of them are true deep-water species, and most may be obtained in water that is quite shallow: indeed, the littorinas recorded and the *Cardium edule* are only usually to be found between tide-marks or a little below that."

The widest foreshores composed of marine alluvia are found in Barrisdale Bay and Loch na Dal. The beaches at Bernera and Tarskavaig are distinguished by their unusually clean fine sand—which is not common in the district—and parts of the shore a few hundred yards south of Rudh' Ard Slisneach are pink with garnet sand, most of which has no doubt been derived from the garnetiferous muscovite-biotite-gneiss (of the Moine series) further east and south-east.

FRESHWATER ALLUVIA.

The freshwater alluvia make no large spreads; the largest, those in the Glenmore and Gleann Beag of Glenelg and Arnisdale Glen, never much exceed a quarter of a mile in breadth even with the addition of the high terraces. A fine series of high terraces—at least eight in number—have been carved out of the 100-feet beach at the mouth of Amhainn Ghuserein, on the south side, and another interesting series is found at the sharp bend of the burn near Strathchomair, the highest of which is about 60 ft. above the level of the adjacent burn: this terrace and the one next below are nearly flat, but the lower ones are steeper and slope much the same as the burn.

SCREES.

It seems doubtful whether the screes, which are common at the foot of many of the steeper crags, are being formed to any appreciable extent under present conditions; perhaps most of them are cotemporaneous with parts of the morainic drift. Scree material is particularly widespread on the upper slopes of Ben Sgriol, where it consists of sharp angular blocks of siliceous Moine schist, and has no doubt given the name to this hill.* On the southern slope it spreads down almost from the top to the 1500-feet contour line, and makes one of the most prominent features in the scenery of Loch Hourn: from near the base a number of strong springs issue which are cold on the hottest day and give rise to a large burn, the one shown on the map on the east side of Creag an Fhithich.

* Mr. J. Mathieson, of the Ordnance Survey, states that the name is a compound of the two Norse words, "Scree" and "Fell."

LANDSLIPS.

On the mainland south of Loch Alsh, large landslips are not common. The biggest, on the hillside west and south-west of Poll a' Mhuineil (Loch Hourn), has a length from north to south of about three-quarters of a mile with an average breadth of not much less, and its formation must have been facilitated by the direction of the local dip of the foliation (of the garnetiferous mica-schist of the Moine series) which is down the hill. On the west of Allt Otha (Arnisdale), where the dip of the foliation is also down the hill, a considerable slip of Lewisian Gneiss rocks has reached down to the burn, and must once have dammed it back and given rise to a small loch, which is now represented by alluvium. In other localities, as, for instance, three-quarters of a mile S.S.E. of Balvraid and about two miles south-east of Inverguseran, considerable slips have occurred on steep slopes in which the foliation dips into the hill.

The south-east side of Beinn na Caillich (Kylerhea, Skye), between the 1750-feet and 1250-feet contours, is broken by an old landslip which is nearly half a mile in length from north-east to south-west: the dip of the Torridonian rocks in this locality is generally down the hill. A smaller slip, which must also have been facilitated by the direction of dip, occurs about a mile slightly east of south of the same hill.

PEAT.

In most localities only the basin-peat, most of which probably represents old filled-up lochans, is shown on the map by colour; but a little west of Suardalan, and also near Amhaoil, some other expanses are shown in the same way.

On the mainland south of Loch Alsh, the spreads of hill-peat are generally not so large as in many other parts of the Highlands, most of the hills being too steep and too quickly drained to favour the growth of moss.

In the part of Skye between Kyleakin and the head of Loch Eishort, on the other hand, the slopes are gentle and are often covered with peat, even when the subsoil is of a loose gravelly character, as on the 100-feet beach. C. T. C.

Skye West of Broadford and Loch Eishort: and Scalpa.

RAISED BEACHES.

To the north-west of Broadford raised beaches are seen on many parts of the coast. In sheltered places, such as the south-western coast of Scalpa, they are continuous for long distances and usually present two well-marked levels, the lower at about 20 ft. and the upper at 100 ft. In more exposed places the higher beach is at most represented by small isolated patches of gravel. In the sea-lochs, as at Kinloch-ainort and Sconser, the lower beach may rise to 30 ft. Beaches at the level of about 50 ft., seen at Strollamus, Dunan, Ard Dorch and elsewhere, may perhaps indicate an intermediate stage. There are, however, places, such as the Braes, where shingle and

gravel extend from the modern beach up to 100 ft. or more without any distinct terracing; and it is clear that newer beaches have been in part formed by the destruction of older and higher ones. On the opposite coast of Skye, from Loch Eishort to Loch Scavaig, there is rarely any trace of beaches higher than that at 20 to 25. ft.

FRESHWATER ALLUVIA.

The larger valleys from Broadford westward, viz. Strath Suardal, Srath Mòr, the Kinloch-Ainort valley and Srath na Creitheach, have considerable alluvial deposits in the more level parts of their courses. In Srath Mòr and Srath na Creitheach also, each of the watercourses which channel the steep slopes has at its foot a delta of boulders; and in the latter valley the accumulations which cover the floor for considerable distances consist of similar boulders, principally of granite. Where the lower part of a valley is of an open character, as in Srath Mòr and the strath above Loch Ainort, the valley deposits pass into the low raised beach at the mouth. A. H.

PEAT.

The peat deposits have not been systematically mapped, but they are known to be tolerably widespread in the flatter areas. An irregular growth of peat occurs on the moorland of the eastern ledge in Strathaird and of the Jurassic tracts in the south of Strath. Better defined deposits fill hollows at various altitudes.

C. B. W.

Raasay.

RAISED BEACHES.

Along the coast bordering the Torridon Sandstone of Eyre, there is a low beach of recent marine gravel and sand, about 20 ft. thick. Traces of this beach occur at Suisnish Point.

At a higher level are the gravelly patches over the boulder clay near Rudha na Cloiche, which extend to about 50 ft. It is interesting to find that Macculloch had noticed these accumulations on Raasay. He observed: "At its southern extremity is found an alluvium of rolled stones, forming a sea bank of an origin which is not apparent; since it is not connected with any river, and is far too high to have been thrown up by the tides. A similar one, but of smaller [larger] extent, is found near Clachan." * H. B. W.

Mainland North of Loch Alsh.

RAISED BEACHES.

The 100-feet raised beach is well developed in this area, and can be traced at intervals round the coast from Fernaig on Loch Carron

* "A Description of the Western Islands of Scotland," 1819, vol. i. p. 242.

to Balmacara on Loch Alsh, beyond the lower limits of the later glaciation. There is, therefore, good ground for believing that this beach was contemporaneous with the extension of the later valley glaciers in this region.

At Fernaig, at the angle made by Srath Ascaig with Loch Carron, one of the finest examples of this high-level terrace is to be found, to which reference has just been made. The materials consist of false-bedded sands and gravels, and the flat surface is largely covered with peat. An Ordnance Survey bench mark at one point on the beach indicates that it there reaches a height of 102 ft. Westwards from Fernaig the terrace is traceable on the coast of Loch Carron on both sides of Duncraig. At the mouth of Loch Carron near Plockton, and for some distance to the south as far as Drumbuie, it forms a large part of the low plateau fringing the sea, and affords an extensive tract of arable land. Near Plockton it is overlaid with peat, the remnant of a wide covering of that deposit which has been in great measure removed. Here again the Ordnance Survey map shows that at a point near Duirinish the height of the terrace is 99 ft.

On the shore of Loch Alsh at Balmacara, indistinct traces of this high-level beach are to be found where the sections show stratified gravels resting on boulder clay.

Within this area also there is a well-marked development of a beach at a lower level, varying in height from 30 to 40 ft. along the outer coast, but reaching a greater elevation when traced up the sea-lochs. It is characterised by a more or less prominent bluff along its inner margin. In those areas where the 100-feet beach is met with, traces of this lower terrace frequently appear fringing the sea. It forms a prominent feature on the shore of Loch Alsh, where it can be followed up the sea-loch beyond the limits of the 100-feet beach to Ardelve, appearing there as a broad plain at the angle between Loch Alsh and Loch Long. At a point a few yards above the junction of the Udalain stream with the sea, Mr. Clough and Dr. Crampton found a deposit of shelly clay which probably represents the sublittoral zone of this beach.

Recent beaches are met with round the coast in sheltered bays. Small patches and spits of sand occur at the mouth of Loch Long connecting Eilean Tioram—a fragment of one of the higher beaches —with the shore at low water.

FRESHWATER ALLUVIA.

The floor of Srath Ascaig is covered with the alluvium of the lake retained by the 100-feet beach at Achmore, to which reference has already been made. Higher terraces occur at Braeintra, marking stages in the erosion of the 100-feet beach barrier after successive uplifts corresponding to lower beaches.

A succession of small patches of alluvium along the course of Gleann Udalain evidently represents silted-up lakes, as already indicated, and similar deposits occur near the mouths of streams where they cut through the raised beaches near the sea.

PEAT.

Peat occurs on the high plateau on each side of Gleann Udalain, in hollows probably representing silted-up lakes on the lower plateau, and especially on the flat surfaces of the various raised beaches where it has been in great part removed for fuel.* B. N. P., J. H.

* In the *Edinburgh Philosophical Journal*, 1829, p. 129, the Rev. Mr. Smith notes the occurrence near the manse of Lochalsh of "a bed of submarine moss extending into the sea considerably below low watermark." This bed was not observed in the course of the survey of that district. Recently careful search has been made for this layer of peat by Mr. Ross, Inverinate, but without success.

CHAPTER XVI.

ECONOMICS.

CHARACTER OF THE GROUND, OCCUPATIONS ETC.

A GREAT part of the mainland south of Loch Alsh is used as deer forest, the area devoted to sport having been much increased in recent years. The remainder provides hill-pasture for sheep and some grouse shooting, with small enclosed stripes of grass land and arable ground, chiefly on river terraces and raised beaches. The extent of cultivated ground is said to be much less than it was one hundred years ago, and old plough-marks and field dykes are still distinct in many parts which are not now enclosed, for instance, near Cnoc Fhinn (the head of Glenmore) and on the coast south-west of Inverguseran. The latter district includes broad patches of the 100-feet beach, and the former is chiefly composed of dioritic and syenitic rocks which readily disintegrate and form ground which is unusually green and fertile, owing presumably to their richness in potash and apatite. No other industry has locally replaced the partially abandoned crofting agriculture, and so the population has greatly decreased and is now almost confined to three or four seaside villages, where fishing can be carried on in addition to some agriculture.

No large plantations exist in this part of the mainland, but some of moderate size, of larch, have thriven well in the lower part of Glenmore, and have lately been greatly thinned. A small plantation of larch, fir, and spruce has recently been planted near Ellanreoch and is thriving, and other sheltered situations could probably be found for afforesting on a large scale. Natural self-sown woods, consisting chiefly of trees of small growth, including birch, hazel, mountain-ash and alder, adorn parts of Gleann Beag and considerable tracts on the north side of Loch Hourn. Scattered groups of the Scottish fir (*Pinus sylvestris*) near the upper part of this loch are said to represent remnants of the old Caledonian forest, but they appear to be gradually dying out, the seedlings never reaching maturity, even in areas where there are no sheep to nibble them and where the birch is spreading quickly.

On the Matheson estate north of Loch Alsh there are extensive woods, in the neighbourhood of Duncraig, which have flourished exceedingly well since they were planted. The planting was begun in 1867, and was carried on for twenty years or more. The trees planted are mostly Scottish fir and larch, but include also oak and beech, and a great variety of pines and flowering shrubs.

The Blath-bheinn range and the Red Hills—Beinn Dearg, Beinn na Caillich (Broadford) and the other hills of granite or granophyre

lying to the north-west of these—are used as deer forest, but the parts of Skye further east and south are chiefly under sheep and contain a considerably larger population than the mainland south of Loch Alsh. In these parts of Skye the hills are not very high nor craggy, and there is no area which is entirely devoted to sport, though stags are occasionally stalked on the hills between Loch Alsh and Loch na Dal, and also near Ord. The lower moors near the head of Loch Eishort and on the south-west side of Loch na Dal generally carry a fair stock of grouse as well as sheep.

The population of Skye is chiefly collected into villages on the sea-board, among which we may name, Broadford, Harrabol, Skulamus, Breakish, Sconser, Strollamus, Kyleakin, Kylerhea, Drumfearn, Isle Ornsay, Saasaig, Tarskavaig, Heast, Torran, Strathaird and Elgol. The first four of these are close together, and form the largest centre of population. In many places the older dwellings have in recent years, especially since the passing of the Crofters Act, been considerably improved or replaced by new ones with better accommodation. Since the railway has been opened to the Kyle of Lochalsh, Kyleakin has grown in importance, being close to the terminus from whence the takes of herring etc., got by many of the fishing fleets, can most conveniently be dispatched. For the fishing grounds of Loch Scavaig and Loch Eishort, however, the railway terminus at Mallaig, which is a few miles south of Airor (southern margin of the Sheet), is the best *rendezvous* whence to dispatch the catch to the southern markets. Salmon netting is systematically carried on along the coast in the season, extending from the 11th of February to the 26th of August, and there is also some lobster fishing off the rockier more exposed parts. A considerable proportion of the able-bodied men generally go away from the island in the summer months, to work in yachts, tourist steamers and herring boats, but this annual migration is probably more than counterbalanced by the influx of sportsmen and summer visitors. The "Isle of Mist" exerts a wonderful attraction on all those who know it, and among mountaineering men the Skye hills have for many years had a wide reputation, as being the best climbing ground in Britain.

A small part only of the Skye area is capable of cultivation. The crofts of Torran are situated on the Cambrian limestones: other crofting hamlets stand on the readily disintegrating granulitic rocks of the Lewisian Gneiss series, or on the Jurassic rocks, or cling to places where the drift provides a subsoil, or extend along the raised beaches. At Strathaird agriculture has lately been attempted on a considerable scale and with modern methods, and by means of fertilisers adapted to the heavy rainfall good crops have been raised. Small crops are raised on the sloping ground of the estuarine shales at Elgol. Some pasturage is afforded by the alluvial flats and salt marshes at the head of Loch Slapin, and by the neighbouring low ground.

Natural self-sown woods, of birch, hazel, mountain-ash etc., grace considerable tracts near the coast of Skye between Port Aslaig and Ardnameacan, and also in the Ord Valley and near Tokavaig. A few small plantations have also been laid out in one or two parts of the island, as on the west side of Broadford Bay and between

Knock and Ostaig; but the first-mentioned are wind-swept and stunted, and most districts are still notoriously bare of trees.

H. B. W., C. T. C., A. H., C. B. W.

COAL.

The local traditions of coal in the country west of the Broadford strath, both in the Oolitic series and in the basaltic group, can only refer to small inconstant seams, quickly exhausted by the residents.

A. H.

MARBLE AND LIMESTONE.

The "Skye marbles," the metamorphosed Cambrian limestones, were in the early part of the last century much valued for ornamental purposes. They were quarried near Cil Chriosd, Strath Suardal, and widely exported, numerous varieties being turned out, as noted by Macculloch.*

A Skye Marble Company has recently been formed, and is now working the metamorphosed limestone in a quarry about a mile and a half north-west of Broadford Church. The quarry lies about a quarter of a mile west of the main road and is connected therewith with a tramway, from the end of which the material is conveyed along the road, downhill, to Broadford pier by cart or road-engine. Mr. W. W. Gunn, the Manager of the Company, kindly informs us that at present (1908) the only material being sold is in the form of small chips, used for the purpose of making mosaic cubes and terrazzo mosaic. He hopes, however, shortly to commence the sale of thin slabs, and afterwards, after thoroughly testing the uniformity of the stone in the slab-making process, to advance to the production of larger blocks. The marble being now quarried is white in the ground mass with many thin irregular veinlets of a delicate dove-colour. It forms part of a mass entangled in gabbro. Trial quarries have also been made by the same Company near Torran, and about three-quarters of a mile slightly west of south of the old church of Cil Chriosd. It is stated that, at the quarry in the locality last mentioned, blocks weighing more than thirty tons have been obtained.

It is hoped that the Skye marble may be found suitable for most of the purposes for which Italian marble is now used. The amount of slab and block marble at present imported into Great Britain from Italy is said to be as much as 36,000 tons, and, in addition to this, many thousand tons of crushed marble are also brought over for mosaic work.

C. T. C., A. H.

The bands of limestone or marble in the Lewisian Gneiss series do not appear to have ever been quarried either for burning for lime or for ornamental purposes. The most common type consists of a white rather coarsely granular matrix of calcite mottled with small white, yellow or greenish spots and streaks, formed of different silicates, which would probably increase the value for various artistic purposes. It is doubtful whether a thickness of 50 ft. could anywhere be found without some admixture of other rock, or whether the beds are sufficiently massive for heavy work. Films of asbestos or fibrous actinolite

* "A Description of the Western Islands of Scotland," 1819, vol. i. p. 399.

frequently traverse the limestone, but have never been found in sufficient thickness to admit of profitable commercial use. The pale blue and violet varieties of spinel, which are found in the marble about 1200 yds. east of Sgiath Bheinn (Glenelg), have a handsome appearance and might possibly be valued as gems, but they are not abundant nor as a rule larger than a pea. C. T. C.

The Lower Lias limestone (belonging to the main group of limestones) is quarried for lime-burning at Broadford.

Some of the bands of limestone in the higher division (characterised by gryphæas) so closely resemble bands of earthy limestone or "cement-beds" of the English Lias, that it seems very probable they could be utilised in the manufacture of hydraulic lime and cement.

Moreover, clay could be obtained in places which would be suitable for mixture with the purer limestones for the manufacture of cement. H. B. W.

The limestones of the Great Estuarine series, of which the upper or Paludina limestones are not sandy, have not been worked: nor have the Lias limestones on Loch Sligachan. C. B. W.

GRANITES ETC.

The Skye granite, which comes to the coast about Loch Ainort, is not of a quality adapted to building. A. H.

The granitic, syenitic and dioritic rocks near the head of Glenmore, Glenelg, are generally either deeply weathered or much jointed, and the common varieties are not of a striking appearance, being of fine grain and devoid of phenocrysts. Some of the varieties of mica-diorite, hornblendite and pyroxenite have, however, a considerable resemblance to the kentallenite or "black granite" of Ballachulish—which is at present highly prized—being distinguished by the presence of large plates of bronze-coloured biotite.

The serpentines are not of types which appear suitable for ornamental purposes, and are frequently mixed with soft talcose rocks containing a considerable proportion of ferriferous carbonate. The purer and less weathered talcose rocks—examples of which are found 300 yds. above the foot of Allt Mòr (Gleann Beag), in the burn 1400 yds. south-east of Tigh Dhruideig (Loch Duich), and in Allt Utha (east of Arnisdale)—are sometimes used locally for rubbing stones for hearths and doorsteps. They give a white streak somewhat like that of French chalk, and are much preferred to the Bath bricks or calm-stones sold in shops. C. T. C.

BUILDING STONES.

Near Broadford the chief building stones are the sandstones, or "freestones" as they are called in distinction from the limestones. These freestones are dug in many places both in the Broadford Beds and the Scalpa Beds, generally as near as possible to the spot where wanted.

Owing to this unsystematic way of extracting stone, the foreshore and even the bordering roadways are sometimes broken into in a serious way. Excellent stone was quarried on the foreshore near to Corry, but so close to the roadway as to damage it. On the south

shore of Ob Breakish the habitations have been protected by a natural pavement of Lias, and this (though sloping) has formed the chief highway for the residents. In places this pavement has been ruthlessly torn up along the very highway itself — leaving great hollows of broken ground and pools of mud and water to interrupt and obstruct every wayfarer. H. B. W.

The highest sandstone of the Inferior Oolite series has been quarried on a very small scale at Keppoch, Strathaird. C. B. W.

In the Sleat district of Skye the Torridonian grits afford a good and very widespread supply of building stone, except along the coast between Isle Ornsay and Ostaig, where the more massive rocks in the Lewisian Gneiss series and some of the Tertiary intrusive dykes are used.

On the mainland south of Loch Alsh durable building stones can be got, in almost unlimited amount, from the Moine schists, as well as from many varieties of rock in the Lewisian Gneiss series. Wherever a building is to be erected good stone can be found not far away, and therefore no large permanent quarries have been developed. C. T. C.

GRAPHITIC SEAMS.

In Chapter X. mention has been made of a thin seam of graphite in describing the Inferior Oolite series under Tòrr Mòr on the north side of Loch Sligachan. There is no reason to suppose that it is of any economic value. It is about eight or nine inches thick, but is impure and only remains above sea-level for a short distance. It no doubt represents a local coal-seam which has been altered, either by the outpouring of the unconformable Tertiary lavas on its denuded surface or more probably by the injection of a basic sill just above it, at the base of the lavas. C. B. W.

The graphitic seams in the Lewisian Gneiss series have sometimes been erroneously regarded as indications of coal. The seams about 730 yds. W.N.W. of the south-west end of Lochan na Beinne Faide, and about 130 yds. S.S.E. of the same end,* are probably the richest which have been observed. The former contains some masses of tolerably pure graphite an inch or more in breadth, but pieces so large as these are not common. The latter is eight or nine inches thick, but the graphite does not form a large proportion of the rock, and it is not probable that either seam could be profitably worked.

METALLIFEROUS SEAMS.

During the last few years, statements in various newspapers have announced the discovery of lodes of gold and copper in the neighbourhood of Loch Duich, and two Welsh miners were employed for some time, in 1904 and 1905, in driving a short day-level to test one of the so-called lodes close to the north-east side of the loch and about a mile and a half south-east of Dornie. The situation is about half a mile east of the eastern margin of the map being described. The level

* The last-mentioned seam was kindly pointed out by Mr. Murdo Murchison, the gamekeeper at Tigh Dhruideig.

is driven in the Lewisian Gneiss series, very near several outcrops of marble. The band which is mined is not a lode with well defined sides crossing the beds, but a gneissose band, five or six feet thick, which is specially rich in pyrites and pyrrhotite. Its outcrop, which is well seen just above the level mouth, weathers with a rusty surface and contains many strings and finely disseminated particles of pyrites, together with small scales of graphite, and it is evidently of essentially the same character as many other outcrops of graphitic gneiss which have been mapped by the Geological Survey in one-inch maps 71 and 72.

Sir Keith Fraser, on whose land the level is situated, states that a sample taken from a block tumbled from the outcrop was found on assay to contain 55 per cent. of iron, 40 per cent. of sulphur, ·25 per cent. of copper, and ·8 per cent. of nickel, in addition to some silver and gold in the proportions of 11 dwt. and 3½ dwt. per ton. But this sample must have been much richer than the average, for out of four specimens —each somewhat richer in the yellow ores than the average samples are—which were collected by the Geological Survey and assayed by Dr. Pollard, the two richest yielded gold at the rate of only 1 dwt. 4 grs. per ton of 2240 lb. A sample from a similar pyritous graphitic band about 933 yds. slightly north of west of Bealary (Glenmore of Glenelg) was also assayed by Dr. Pollard, and was found to contain only 1 dwt. 1 gr. per ton of 2240 lb., so that it seems improbable that these graphitic pyritous bands—the more important of which are shown on the published map—will prove to be profitable sources of gold.

In the bed of the burn about 400 yds. slightly east of north of Srathchomair a vein of galena, from four to six inches broad but mixed with small specks of ferriferous carbonate and copper pyrites, crosses a crumpled biotite-schist belonging to the Lewisian Gneiss series. It hades S.S.W. and strikes N.N.W., but it can only be traced a few yards, and perhaps thins away rapidly in a N.N.W. direction. A sample, assayed at Newcastle-on-Tyne (but it is not known by whom), is said to have contained silver in the proportion of 65½ ozs. per ton of lead.

A few strings of quartz with copper pyrites cross the hornblende schist in the Lewisian Gneiss series in a small island about a quarter of a mile W.S.W. of Rarsaidh (Loch Hourn), but they are much too thin to be of economic value.

Eclogite has been shown by Professor Bonney to be the parent rock of the diamond in South Africa.* In consequence of this, some heavy residues were collected by washing the stream gravels in Allt Mòr Shantaig, rather more than three miles S.S.W. of the Kirkton of Glenelg, a burn draining an area in which eclogite and the allied rocks are unusually widespread. But no diamonds were discovered.

GRAVELS ETC.

The materials used for mending the roads—on none of which is the traffic heavy—are generally obtained from neighbouring superficial deposits, for example, the gravels of the raised beaches and morainic

* "The Parent Rock of the Diamond in South Africa," *Proc. Roy. Soc.*, 1899, vol. lxv. p. 223.

drift. A small quantity is dug out near the roadside from shallow pits or open cuts, and this is wheeled along in barrows for a certain distance, beyond which another supply is similarly obtained.

Near Inverguseran the gravels in the present and the 20-feet beach are very clean, being for the most part composed of pebbles of siliceous Moine schist. They are occasionally shipped in smacks to more populous districts for garden use.

PEAT.

The more accessible peat mosses are of considerable local importance as sources of fuel, though a supplementary supply of coal is often brought in by sea. In order to save the labour of transport, it is customary to cut those peat mosses which are nearest to the consumer's house, even though these mosses may be very small and shallow. The peat sods are cut in the spring—the driest season of the year—and at once spread out to dry. They are generally stacked at the side of the moss, even if this be far away from the home; and in many localities the women have to make long journeys day by day to bring them in, even in wild wintry weather and along steep slippery paths. This procedure is said to be adopted because the winter is a season of comparative leisure, when no other outdoor work is pressing.

POSSIBILITIES OF WATER POWER.

Owing to the heavy rainfall and the rapid slope of some of the burns, it seems not impossible that in the future some of these may be used as sources of power for various industries; but any power that could be obtained from the streams would probably be small in comparison with the force of the tides which rush through the sounds of Kyle Rhea, Kyle Akin, and the "Narrows" of Dornie in immense swirling masses, against which some of the less powerful steamers can make little or no headway. C. T. C.

APPENDIX.

I. PALÆONTOLOGICAL.

1. LIST OF CAMBRIAN FOSSILS.

By B. N. Peach, LL.D., F.R.S.

Below is given a list of localities from which Cambrian fossils have been obtained in the one-inch map being described, together with a list of the fossils found. In the first list the localities are designated by numbers, and these numbers are used in the fossil list to indicate the localities at which the different fossils have been got.

List of Localities.

(1) Top of limestone knoll, Suardal; 1½ ml. S.S.W. of Broadford Hotel. (Ben Suardal zone of Durness Limestone.)
(2) West side of Bealach a' Ghlinne, 1¾ ml. south of Broadford Hotel.
(3) South slope of Ben Suardal. (Ben Suardal zone of Durness Limestone.)
(4) Ben Suardal, south side of Bealach a' Ghlinne. (Ben Suardal zone of Durness Limestone.)
(5) West side of Ben Suardal. (Ben Suardal zone of Durness Limestone.)
(6) Slope east of turnpike road, Suardal. (,, ,, ,, .)
(7) At Loch Lonachan. (,, ,, ,, .)
(8) Slope N. and N.W. of Loch Lonachan. (,, ,, ,, .)
(9) Slope west of Allt a' Mhuilinn. (,, ,, ,, .)
(10) Torran, shore of Loch Slapin. (,, ,, ,, .)
(11) Island in Ord Bay. (Serpulite Grit.)
(12) Shore of Loch Eishort, ½ ml. N.N.E. of Ord. (Fucoid shales.)
(13) ,, ,, ,, ("Pipe-rock" division of quartzite.)
(14) Burn at head of wood ¾ ml. east of Tokavaig. (Fucoid shales.)

List of Fossils.

Spongida.	Locality Number.
Archæoscyphia *Hinde*	.
,, minganensis (*Bill.*)	1, 2, 3, 4, 5, 8.
,, sp.	1, 2, 3, 4, 6.
Calathium *Billings*	.
,, anstedi *Bill.*	9.
,, calciferum (*Bill.*). [Receptaculites *auct.*] .	4, 5.
,, elegantulum (*Bill.*). [Receptaculites *auct.*] .	2, 4.
,, pannosum *Bill.*	7.
,, sp.	1, 2, 3, 5, 7, 8.
Rhabdaria *Billings*	.
,, sp.	1, 2, 4, 5, 8, 9.
Trichospongia *Billings*	.
,, sp.	1, 5, 8.
Sponge, indet.	1, 2, 7.

ANNELIDA.	LOCALITY NUMBER.
Scolithus *Hall*	
,, linearis *Hall*	13.
,, sp. (" common pipes ")	13.
,, sp. (" trumpet pipes ")	13.
,, sp. (the so-called " fucoids ")	12.

TRILOBITA.	
Olenelloides *Peach*	
,, armata *Peach*	14.
Olenellus	
,, reticulatus *Peach*	14.
,, sp.	14.
Solenopleura *Angelin*	
,, tumida ? *Walcott*	8.
Trilobite fragment (not Olenellus)	12.

BRACHIOPODA.	
Billingsella *Hall and Clarke*	
,, festinata (*Bill.*). [Orthisina *auct.*]	4, 8.
,, grandæva (*Bill.*). [Orthisina *auct.*]	8.
Dalmanella *Hall and Clarke*	
? ,, testudinaria (*Dalman*). ["Orthis striatula" *Salter*]	8.

LAMELLIBRANCHIATA.	
Euchasma *Billings*	
,, blumenbachi *Bill.*	1, 3.
,, ,, *var.* i.	9
,, ,, *var.* ii.	9.

GASTEROPODA.	
Chelodes *Davidson and King*	
,, sp.	1.
Holopea *Hall*	
,, ophelia *Bill.*	1.
Maclurea *Lesueur*	
,, acuminata *Bill.*	1.
,, crenulata *Bill.*	1, 2, 4, 8, 10.
,, emmonsi *Bill.*	1, 6, 8.
,, oceana *Bill.*	2, 3, 4, 5, 6, 7, 8.
,, peachi *Salt.*	1, 3, 4, 5, 6, 8, 10.
,, sp. i. (operculum)	1, 2, 4, 8, 9.
,, sp. ii. (,,)	1, 2, 3, 4, 5, 6, 8.
,, sp. iii. (,,)	1, 2, 3, 4, 5, 6, 8.
,, sp. iv. (,,)	1, 5, 6.
,, sp. v. (,,)	1, 2, 8, 9.
Ectomaria *Koken*	
,, adelina (*Bill.*)	8.
,, pagoda (*Salter*)	1, 3, 6, 8, 10.
,, ,, *var.* orientalis *Donald*	1, 2, 4, 6, 8.
,, ,, *var.* peachi *Donald*	2.
Hormotoma *Salter*	
,, anna (*Bill.*)	3, 8, 10.
,, artemisia (*Bill.*)	2.
,, bellicincta (*Hall*)	4.
,, gracilis (*Hall*)	2.
,, gracillima *Salt.*	2.
Lophospira *Whitfield*	
,, augustina (*Bill.*)	1, 3.
,, borealis *Donald*	1, 4.
Murchisonids	8, 14.
Ophileta *Vanuxem*	
,, compacta *Salt.*	3, 8.
,, complanata *Vanx.*	8.

Gasteropoda—*continued.*	Locality Number.
Ophileta nerine *Bill.*	2.
,, sp.	8.
Trochonema *Salter*	
,, calphurnium (*Bill.*). [Pleurotomaria *auct.*]	8.
Omphalotrochus *Meek.* [Oriostoma *auct.*]	
,, sp. *var.* i.	9.
,, sp. *var.* ii.	9.
,, sp.	1, 7, 8.
,, sp. (near Pleurotomaria, ribbed)	2.
Euconia *Ulrich*	
,, beekmanensis ? (*Whitf.*)	10.
,, ramsayi (*Bill.*)	1.
Raphistomina *Ulrich and Scofield*	
,, laurentina (*Bill.*)	1, 2, 3, 5, 7.
,, ? calcifera (*Bill.*)	1, 2, 5, 7.
"Pleurotomaria" turgida *Hall*	1, 3, 5.
Pleurotomarid	2.
Cephalopoda.	
Actinoceras *Bronn*	
,, ? mendax (*Salt.*). [Orthoceras *auct.*]	2, 3, 4, 5, 7, 8.
Endoceras *Hall.*	
,, sp. i.	8.
,, sp. ii.	5.
,, sp.	1, 2, 8.
Orthoceras *Breynius*	
,, baculoide *Blake* (=siphuncle of an Endoceras)	1.
,, durinum *Blake* (= ,, ,, ,,)	1, 2, 9.
,, pertinens *Blake*	1, 2, 3, 4, 6, 8.
,, sp.	1, 6, 10.
Piloceras *Salter.*	
,, invaginatum *Salt.*	1, 2, 3, 4, 5, 8.
,, ,, *var.* i.	5, 8.
,, ,, *var.* ii.	1, 2, 3, 8.
,, ,, *var.* iii.	1, 8.
,, sp.	4.
Trocholites *Conrad*	
,, sp. i.	7.
,, sp. ii.	1, 7.
Incertæ sedis.	
Planolites *Nicholson* [=worm-casts]	Many localities.

II. LISTS OF MESOZOIC FOSSILS.

Drawn up by F. L. Kitchin, M.A., Ph.D., and C. B. Wedd, B.A., F.G.S.

The following lists of fossils are based upon suites of specimens which have been named from time to time by Messrs. G. Sharman, E. T. Newton and F. L. Kitchin. Nearly all the ammonites have more recently been examined and renamed by Mr. S. S. Buckman.

The numbers in the vertical columns of the tables refer to the correspondingly numbered descriptions of localities which follow each table of fossils.

When a locality-number in the table is preceded by a note of interrogation, this denotes that the determination of the specimen from that locality is doubtful.

The name of an ammonite-zone or a stratigraphical division appended

to the record of a fossil in the lists, denotes that the fossil occurs in that zone or division within the district.

In the lists of localities, numbered as far as possible in topographical order, the register-numbers of the specimens from each locality are given in square brackets.

i. Passage-Beds.

Genera and Species.	Strath.	Loch Sligachan.	Raasay.
Plant remains	1, ? 2, ? 3	..	..
Modiola sp.	..	..	6
Myophoria ?	1	..	..
Mytilus sp.	1	..	..
Ostrea sp.	1, 3	5	..
Pecten valoniensis *Defr.*	..	5	? 6
Pleuromya *cf.* crowcombeia *Tate*	..	..	6
Pleuromya ?	1	..	..
Lamellibranchs, indet.	2, 4	..	..
Cerithium semele ? *J. Mart.*	1	..	..
Natica ?	1	..	..
Fish scales	3	..	..

List of Localities.

1. Ob Lusa. 4 miles E.N.E. of Broadford. 8 ft. below the coral limestone. [T. 3586–3597, T. 3623–3630.]
2. Allt a' Mhuilinn. North of Strath. 22 ft. S. of junction with Allt a' Choire and to the S.W. of Manse of Broadford Free Church. [T. 3702–3728.]
3. Heast Cascade. 2 ft. from top of main leap. Top beds of Passage-Beds. [T. 3598–3606.]
4. Heast Cascade. [T. 3607–3612.]
5. Eas Mòr, Sconser. 420 yds. from road, about 4 ft. above rock in waterfall at bend in burn. [C.B.W. 579, 579[1].]
6. Eyre Burn, Raasay. [H.B.W. 1152–1155.]

ii. Lower Lias.

Genera and Species.	Strath, including the Srath Beag outlier.	Pabba.	Blath-bheinn.	Loch Sligachan.	Ammonite Zones: BI–IV = divisions of Broadford Beds; P = Pabba Shales.
Plant remains	68	..	..	..	Raricostatus.
Wood	..	..	..	79	,,
Coral [possibly Thecosmilia; in limestone]	..	..	..	82	BII.
Pentacrinus sp.	38, 64, 68	62	..	79, 87	..
Crinoid fragments.	..	62	..	..	P.
Echinoid ,,	21	..	..	..	BII.
Ditrupa circinata *Tate*	..	62	..	..	P.
Serpula sp.	? 63	62	..	..	Jamesoni.

Genera and Species.	Strath, including the Strath Beag outlier.	Pabba.	Blath-bheinn.	Loch Sligachan.	Ammonite Zones: BI–IV = divisions of Broadford Beds; P = Pabba Shales.
BRACHIOPODA.					
Rhynchonella fodinalis ? *Tate*	..	62	..	..	P.
,, *cf.* furcillata *Theod.*	..	62	..	..	,,
,, *cf.* tetrahedra (*J. Sow.*)	..	62	..	..	Jamesoni.
,, sp.	6, 63, 68	62	..	85,86, 88, 89	..
Spiriferina pinguis ? (*Ziet.*)	..	..	..	89	P.
,, *cf.* walcotti (*J. de C. Sow.*)	31	62	..	..	Jamesoni.
,, sp. nov. ?	..	62	..	..	P.
Terebratula punctata *J. Sow.*	..	62	..	..	Jamesoni.
,, sp.	..	62	..	85, ? 89	..
LAMELLIBRANCHIATA.					
Anomia ?	1	..	..	..	BI.
Astarte sp.	23	..	..	..	BII.
Cardinia concinna ? (*J. Sow.*)	1*a*	..	..	..	,,
,, sp.	? 31, 46	..	..	..	..
Cardita multicostata ? (*Phill.*)	..	..	..	88, 89	P.
Cucullæa sp.	..	..	..	? 76, 89	,,
Gryphæa arcuata *Lam.*	4, 6, 12, 14, 15, 34	? 62	..	..	Buckl.; Semicost.; Raricost. ?
,, cymbium *Lam.*	43, 46, 55	62	..	? 79	Raricost. or Armat.; Jamesoni.
,, sp.	26, 35, 63	..	..	..	..
Hippopodium ponderosum *J. Sow.*	..	..	..	81	Raricostatus.
Inoceramus dubius *J. de C. Sow.*	..	62	..	..	Jamesoni.
Lima antiquata *J. Sow.*	64	..	..	73	..
,, (Plagiostoma) gigantea (*J. Sow.*)	4	62	..	..	Bucklandi.
,, *cf.* hettangensis *Terquem*	64	..	..	..	P.
,, pectinoides (*J. Sow.*)	..	..	..	89	,,
,, *cf.* ,, ,,	50, 66	..	..	..	Semicost.; Raricost. or Armat.
,, succincta ? *Schloth.*	..	62	..	..	P.
,, sp.	67	..	..	? 76, ? 90	..
Lucina ?	1*a*	..	..	..	BII.
Modiola *cf.* numismalis *Oppel*	..	62	..	..	P.
,, scalprum *J. Sow.*	42, 53, 55	62	..	..	Raricost.; Armat. ?
,, sp.	25, ? 68	..	..	? 87	..
Mytilus ? ?	1	..	..	..	BI.
Nuculana tatei *E. T. Newton*	..	..	..	75	Armatus ?
Ostrea irregularis *Münst.*	..	62	..	..	Jamesoni.
,, sp.	1, 63, ? 64 68	62	..	? 86, ? 87	..
Pecten (Chlamys) *cf.* acuticostatus *Dum.*	..	..	..	79	Raricostatus.
,, ,, æquivalvis *J. Sow.*	..	..	..	89	P.
,, ,, *cf.* ,, ,,	..	62	..	..	,,
,, ,, *cf.* dentatus *J. de C. Sow.*	..	62	..	..	,,
,, (Syncyclonema) liasianus *Nyst*	..	62	..	79	Raricost.; Jamesoni.
,, *cf.* subulatus *Münst.*	30	..	..	..	Armatus ?
,, (Chlamys) textorius (*Schloth.*)	27	..	..	78	Buckl. ?; Semicost.
,, ,, thiollieri *J. Mart.*	..	62	..	..	Jamesoni.
,, spp.	41, 42, 61, 63, ? 64, 65, ? 67, 68	62	..	76, 77, 87, 88, 89, ? 90	..
Pholadomya ambigua (*J. Sow.*)	24	62	..	..	Armat. ?; Jamesoni.
,, *cf.* ,,	45, 51	..	..	..	Raricost. or Armat.
,, sp.	16, 32, 33, 40, 46, 64	62	..	89	..
Pinna folium ? *Phill.*	..	62	..	..	P.
,, sp.	48, 68	..	..	..	Raricost. ? Armat. ?

Genera and Species.	Strath, including the Srath Beag outlier.	Pabba.	Blath-bheinn.	Loch Sligachan.	Ammonite Zones: BI–IV = divisions of Broadford Beds; P = Pabba Shales.
LAMELLIBRANCHIATA—continued.					
Pleuromya costata (*Y. and B.*)	..	62	..	..	P.
,, sp.	9, ? 27	? 62	..	? 89	BIV.
Plicatula sp.	1, 30, 63, 68	? 62	..	86, 88, 89	BI, P.
Protocardia truncata (*J. de C. Sow.*)	29	..	..	..	Armatus ?
,, sp.	..	62	..	..	P.
Pteria (Oxytoma) inæquivalvis (*J. Sow.*)	?19, 26, 68, 69	62	..	83	Semicost.—Jamesoni.
,, sp.	63, 64	..	..	..	..
Unicardium cardioides (*Phill.*)	33	62	..	74, 80	Raricost.—Jamesoni.
,, ?	..	..	..	89	P.
Lamellibranchs, indet.	28	..	..	..	..
GASTEROPODA.					
Amberleya imbricata (*J. Sow.*)	..	62	..	..	Jamesoni.
,, *cf.* ,,	..	62	..	..	P.
,, sp.	46	..	..	..	Raricost. or Armat.
Cerithium sp.	42	..	..	..	Raricostatus.
" Chemnitzia " trivia ? *Tate*	..	..	..	88	P.
Natica sp.	1	..	..	..	BI.
Pleurotomaria anglica ? (*J. Sow.*)	36	..	..	..	Raricost. or Armat.
,, sp.	39	..	..	..	Obtusus.
CEPHALOPODA.					
Nautilus *cf.* striatus *J. Sow.*	53	62	..	..	Raricost. or Armat.
? Acanthopleuroceras margatum (*Quenst.*)	..	62	..	..	Jamesoni.
Acanthopleuroceras molare *Hyatt*	..	62	..	..	Jamesoni ?
,, sp.	..	62	..	..	Jamesoni ?
Agassiceras spinaries (*Quenst.*)	59	..	..	..	Semicostatus ?
Amblycoceras *cf.* dudressieri (*d'Orb.*)	16	..	..	..	..
,, *aff.* planicosta (*J. Sow.*)	16, 39	..	..	..	Obtusus.
,, xiphus (*Ziet.*)	16	..	..	..	..
Arietites fowleri (*J. Buckm.*)	? 17, 18	..	..	..	Obtusus ?
? ,, impendens (*Y. and B.*)	39	..	..	..	Obtusus.
Arnioceras bodleyi (*J. Buckm.*)	11, 34*	..	..	..	Semicostatus.
,, ceratitoides (*Quenst.*)	2	..	..	..	BIV.
,, *aff.* cuneiforme *Hyatt*	5	..	..	..	Semicostatus.
,, falcaries (*Quenst.*)	7	..	..	..	Semicostatus ?
,, geometricum ? (*Oppel*)	..	..	..	83	Semicostatus.
,, *cf.* ,,	..	..	72	..	,,
,, hartmanni (*Oppel*)	? 14, 34*	..	..	..	,,
,, robustum (*Quenst.*)	6	..	..	..	BIV.
,, spp.	2, 10, 16, 57, 58, 60*	..	..	? 84	Semicost.; basc of Raricost. ?
,, ?	26, 67	..	71	..	Semicostatus.
Asteroceras brookei (*J. Sow.*)	37, 39	..	..	..	Obtusus.
,, *aff.* ,,	16	..	..	..	..
? ,, redcarense (*Y. and B.*)	16	..	..	..	Obtusus ?
Asteroceras *aff.* smithi (*J. de C. Sow.*)	39	..	..	..	Obtusus.
,, stellare ? (*J. Sow.*)	39	..	..	..	,,
,, suevicum (*Quenst.*)	16	..	..	..	Obtusus ?
,, *cf.* ,,	37	..	..	..	Obtusus.
,, sp.	6	..	..	..	BIV.
? Coroniceras aussoniense (*Reynès*)	59	..	..	..	Semicostatus ?
Coroniceras gmuendense (*Oppel*)	4	..	..	..	Bucklandi.

* Indicated on the one-inch map as "*Am. semicostatus.*"

Genera and Species.	Strath, including the Strath Beag outlier.	Pabba.	Blath-bheinn.	Loch Sligachan.	Ammonite Zones: BI–IV = divisions of Broadford Beds; P = Pabba Shales.
CEPHALOPODA—continued.					
Coroniceras lyra *Hyatt*	7, 9	..	..	..	Bucklandi.
? ,, ,,	4, 13	..	..	..	,,
Coroniceras *cf.* lyra *Hyatt*	20	..	..	..	..
,, *cf.* trigonatum *Hyatt*	3	..	..	..	Bucklandi.
,, sp. [Arietites bucklandi *Wright*, non *Sow.*]	3	..	..	..	,,
,, ?	59	..	..	..	Semicostatus ?
Deroceras armatum (*J. Sow.*)	52	..	..	..	Raricost. or Armat.
,, *aff.* ,,	47	..	..	..	Raricost. or Armat.
? ,, davoei (*J. Sow.*)	49	..	..	..	Armatus.
Deroceras *cf.* marshallani (*Simps.*)	..	62	..	..	,,
,, muticum (*d'Orb.*)	22, ? 67	..	..	..	Raricost. ? ; P.
,, *aff.* ,,	43,* 52	..	..	..	Raricost. or Armat.
? ,, *aff.* ,,	41	..	..	..	Raricostatus.
Deroceras sp.	45, 52	..	..	..	Raricost. or Armat.
Echioceras edmundi (*Dumort.*)	55	..	..	81	Raricostatus.
,, *aff.* ,,	42	..	..	81	,,
,, *aff.* lævidomus (*Quenst.*)	42	..	..	..	,,
,, macdonelli (*Portl.*)	19, 51	..	..	76	Raricost. or Armat.
,, nodotianum (*d'Orb.*)	45	..	..	..	,, ,,
,, *aff.* ,,	36,51,? 52, 55	..	..	..	,, ,,
,, raricostatum (*d'Orb.*)	38, 41, 42, 44, ?67, ?68	..	..	..	Raricost.; Armat. ?
? ,, tardicrescens (*Blake*) [non *Hauer*]	46	..	..	..	Raricost. or Armat.
? ,, *aff.* ,, (*Dumort.*) [non *Hauer*]	46	..	..	..	,, ,,
Echioceras sp.	36,† 42	..	..	..	,, ,,
,, ?	56, 66, 67	..	70	..	Raricostatus.
? Liparoceras intracapricornum (*Quenst.*)	16	..	..	..	..
? ,, *cf.* ,,	24	..	..	..	P.
Liparoceras vesta (*Reynès*)	16	..	..	..	..
,, ?	39	..	..	..	Obtusus.
Lytoceras salebrosum *Pompeckj*	16	..	..	..	..
Lytoceratid fragment	52	..	..	..	Raricost. or Armat
"Microceras" subplanicosta (*Oppel*)	42, 43, 52, ? 67	..	..	..	Raricost.; Armat. ?
Microderoceras *cf.* heberti (*Oppel*)	..	62	..	..	P.
,, quadrarmatum? (*Dumort.*)	..	62	..	..	Armatus.
Oxynotoceras *aff.* lotharingum (*Reynès*)	..	62	..	..	Armatus ?
? Platypleuroceras latæcosta (*J. de C. Sow.*)	39	..	..	..	Obtusus.
Polymorphites bronni (*Roem.*)	8	..	..	..	BIV ?
,, *cf.* caprarius (*Quenst.*)	..	62	..	..	P.
,, *cf.* quadratus (*Quenst.*)	..	62	..	..	,,
? Tropidoceras masseanum (*d'Orb.*)	..	62	..	..	,,
Uptonia angusta (*Quenst.*)	..	62	..	..	Jamesoni.
? ,, costosa (*Quenst.*)	..	62	..	..	,,
Uptonia jamesoni (*J. de C. Sow.*)	..	62	..	..	,,
,, reynardi (*d'Orb.*)	..	62	..	..	,,
Belemnites acutus ? *Mill*	..	62	..	..	P.
,, breviformis *Voltz*	..	62	..	..	,,
,, *cf.* calcar *Phill.*	..	..	..	89	,,
,, *cf.* milleri *Phill.*	..	62	..	..	,,
,, sp.	45, 54, 63, 68	62	..	76, 77, 88	..

* Indicated on the one-inch map as "*Am. armatus.*"
† Indicated on the one-inch map as "*Am. raricostatus.*"

List of Localities.

1. Ob Lusa, 4 miles E.N.E. of Broadford: band on which the coral limestone rests. [T. 3574–3585, T. 3622.]
1*a*. Coast between Lusa and Breakish: low reef on shore in southerly bend of Abhuinn Ashik at its mouth; and nearest to wall, where it crosses the stream. [C.B.W. 312, 313.]
2. Islet S. of Eilean Rugach, near Rudha Ardnish. [H.B.W. 928, 929.]
3. S. of Ardnish. [H.B.W. 882–884.]
4. E. of Ardnish. [H.B.W. 883, H.B.W. 887, H.B.W. 892–894.]
5. Rudha Ardnish. [H.B.W. 888 and 889, H.B.W. 1069.]
6. N. of Ardnish. [H.B.W. 885, 886, H.B.W. 895–899, H.B.W. 1012.]
7. Ardnish. [H.B.W. 989–995.]
8. Ardnish, N. of Ob Breakish. [C.B.W. 321.]
9. E.N.E. of Rudh' Achadh a' Chùirn. [H.B.W. 1009, 1010.]
10. Rudh' Achadh a' Chùirn (coast, south of); Broadford. [H.B.W. 923.]
11. Sgiabain. [H.B.W. 906.]
12. S. of Harrabol. [H.B.W. 901, 902.]
13. Shore-reefs at Glas Eilean, N.E. of Harrabol. [H.B.W. 932.]
14 and 15. Broadford. [H.B.W. 737–741, H.B.W. 900.]
16. N.W. of Corry, Broadford. [H.B.W. 903–905, H.B.W. 921, 922, 933, and 996, H.B.W. 1000–1008, H.B.W. 1013.]
17. N.W. of Corry, Broadford; E. of old crofts. [H.B.W. 927.]
18. N.W. of Corry; between crofts. [H.B.W. 1067.]
19. Camas na Sgianadin. [H.B.W. 890, 891, H.B.W. 924–926, 998.]
20. Coire Buidhe, Central Strath. [H.B.W. 930 and 931.]
21. Escarpment 100 yds. W. of Loch an Droma Bhain. [C.B.W. 308.]
22. S. of Loch na Starsaich. [H.B.W. 999.]
23. Limestone scarp S. of road to Heast; immediately W. of source of burn at Lòn Buidhe. [C.B.W. 307.]
24. Allt na Heast. [H.B.W. 986–988.]
25. Heast, near base of Lias. [C.B.W. 637.]
26. Heast; Gryphæa Beds. [C.B.W. 638, 639.]
27. Heast, 1½ miles N.N.E. of; by Chalybeate Well. [H.B.W. 1018, 1019.]
28. Glen Boreraig, S. bank of Allt a' Ghairbheid, 600 yds. N.E. of Dun Kearstach. [C.B.W. 297.]
29. Southern Strath, 150 yds. N.W. of Loch Fada. [C.B.W. 643.]
30. 200 yds. N.W. of Loch Fada. [C.B.W. 641–642.]
31. Southern Strath; Allt a' Mhuilinn, just below basalt sill. [C.B.W. 494, 495.]
32. Allt a' Mhuilinn, 130 yds. E. of footpath. [C.B.W. 496, 497.]
33. Southern Strath; Suishnish, close to east end of dyke on map. [C.B.W. 526–528.]
34. Boreraig; shore on west side of waterfall. [C.B.W. 571–578.]
35. Boreraig. [C.B.W. 640.]
36. North shore of Loch Eishort; Creag an Daraich (east of Càrn Dearg), about 200 yds. E. of waterfall; sandy shales below sandstone in top of cliff, and E. of fault. [C.B.W. 566–568.]
37. Shore 150 yds. E. of mouth of burn from Creag an Daraich. [C.B.W. 563–565.]
38. Creag an Daraich, a few yds. S.E. of waterfall: lower part of high cliff. [C.B.W. 569, 570.]
39. Low cliff on shore half-way between Allt na Feaden (next burn E. from Càrn Dearg) and burn from Creag an Daraich. [C.B.W. 545–560.]
40. Shore E. of mouth of Allt na Feaden. [C.B.W. 561.]

41. Lower part of cliff, about 70 yds. E. of gabbro of Càrn Dearg. [C.B.W. 529–533.]
42. Lower part of cliff, about 300 yds. W. of spot where gabbro of Càrn Dearg comes down to shore. [C.B.W. 534–544.]
43. North shore of Loch Eishort, half-way between Calaman and gabbro of Càrn Dearg; 200 yds. E. of the burn Bas-nan-Coin. [C.B.W. 507–511.]
44. Shore 40 yds. W. of Bas-nan-Coin. [C.B.W. 503–506.]
45. Shore 120 yds. W. of Bas-nan-Coin. [C.B.W. 498–502.]
46. Calaman; shore on S.E. side of promontory. [C.B.W. 513–525.]
47. Calaman; shore on S.W. side of promontory. [C.B.W. 512.]
48. East shore of Loch Slapin; 300 yds. S. of Stac Suisnish. [C.B.W. 477.]
49. Sandstone in cliff, N. of Stac Suisnish. [C.B.W. 627.]
50. Coast 300 yds. N. of Stac Suisnish. [C.B.W. 478.]
51. Coast 350 yds. N. of Stac Suisnish. [C.B.W. 479–481*a*.]
52. Coast 600–700 yds. N. of Stac Suisnish. [C.B.W. 482–493.]
53. Coast 450 yds. N. of Stac Suisnish; band of sandstone. [C.B.W. 628, 629[1].]
54. Coast N. of Stac Suisnish; sandstone beds. [C.B.W. 630.]
55. Coast near Stac Suisnish. [C.B.W. 631–635.]
56. East shore of Loch Slapin, S. of Glen Boreraig: cliff 750 yds. N. of Stac Suisnish. [C.B.W. 296.]
57. Stream just S. of Allt a' Ghairbheid, about 50 yds. from shore. [C.B.W. 294.]
58. Shore, north side of Allt a' Ghairbheid. [C.B.W. 293.]
59. Shore of Loch Slapin on north side of Allt a' Ghairbheid. [C.B.W. 289–291.]
60. Shore of Loch Slapin about 120 yds. S. of mouth of Allt Lèth Slighe. [C.B.W. 295.]
61. Shore 110 yds. N.W. of mouth of Allt Lèth Slighe; about 20 ft. above lowest bed of Lias overlapping on Durness Limestone. [C.B.W. 311].
62. Isle of Pabba. [T. 3631–3701; C.B.W. 281–288; H.B.W. 907–920, H.B.W. 934–983.]
63. Torran; Allt Slapin, at bend of stream a few yds. above crofter's dyke at fault bringing in Durness Limestone. [T. 4645–4659.]
64. Allt Slapin, about 150 yds. above same fault. [C.B.W. 298–302, C.B.W. 476, 476[1].]
65. Lower slope of Beinn Dearg Mòhr, close to lava, 550 yds. N.W. of Allt Slapin (Torran District). [C.B.W. 466.]
66. Allt an t-Sratha Bhig, 370 yds. S. of granophyre. [C.B.W. 470–475.]
67. Allt an t-Sratha Bhig, about 750 yds. N. of junction with lowest tributary on one-inch map. [T. 4845–4867.]
68. Allt an t-Sratha Bhig; about ½ mile from mouth of stream and 200 yds. N. of its westward bend at a sharp double bend in stream followed to N. by alluvial patch. [T. 4750–4784.]
69. Allt an t-Sratha Bhig; angle in burn 200 yds. N. of westward bend. [C.B.W. 467–469.]
70. South of Blath-bheinn; small burn running into Abhuinn nan Leac, from east side, 600 yds. N.E. of waterfall. [C.B.W. 433.]
71. Upper part of Abhuinn nan Leac, east branch, 100 yds. above fork of stream. [C.B.W. 430, 431.]
72. S.W. slope of Blath-bheinn, above limestone. [C.B.W. 432.]
73. Sconser; small burn 300 yds. E. of Schoolhouse, and 60 yds. S. of road. [C.B.W. 580.]
74. Same burn, 250 yds. S. of road. [C.B.W. 581, 581*a*.]

75. Small burn 100 yds. E. of Sconser Schoolhouse, 50 yds. S. of road. [C.B.W. 582, 582*a*.]
76. Same burn, 300 yds. S. of road. [C.B.W. 583–587.]
77. Upper part of burn that passes close to School, 150 yds. S. of basalt scarp. [C.B.W. 590–593.]
78. Small burn 80 yds. W.S.W. of School. [C.B.W. 588, 589.]
79. Shore of small promontory, N.W. of School. [C.B.W. 617–622.]
80. Shore of Loch Sligachan, 250 yds. N.W. of School, near sharp bend in road and W. of small promontory. [C.B.W. 615.]
81. Shore of Loch Sligachan, 300 yds. W.N.W. of School and 100 yds. W. of sharp bend in road. [C.B.W. 610–614[1].]
82. Sconser; west side of burn flowing W. of disused School (situated on road 550 yds. S.W. of bend above mentioned), near bend in burn 150 yds. S. of road. [C.B.W. 608.]
83. Burn flowing close by and E. of disused School, 50 yds. S. of road. [C.B.W. 597–603.]
84. Burn W. of disused School, Sconser, 50 yds. S. of road. [C.B.W. 605.]
85. South side of Loch Sligachan; a few yards W. of burn flowing from Leathad Dubh, the second burn from western margin of one-inch map, and about 100 yds. S. of road. [C.B.W. 623, 626.]
86. Same burn, 5 yds. S. of road-bridge. [T. 4868–4875.]
87. Same burn, 20 yds. N. of road-bridge. [T. 4876–4881.]
88. Same burn, 35 yds. N. of road-bridge. [T. 4882–4892.]
89. Same burn, 40 yds. N. of road-bridge. [T. 4893–4915.]
90. Same burn, lower down, where shales pass under lava of Tôrr Dubh, on coast N. of Leathad Dubh. [C.B.W. 624, 625.]

iii. Middle Lias.

Genera and Species.	Scalpa.	Strathaird.	Ammonite Zones.
Serpula sp.	1	3	Spinatus.
Ornithella perforata (*Piette*)	..	4	,,
Rhynchonella acuta (*J. Sow.*)	..	4	,,
,, *cf.* furcillata (*Theod.*)	..	4	,,
,, tetrahedra (*J. Sow.*)	..	2, ? 4	,,
,, sp.	..	4	,,
Spiriferina sp.	..	4	,,
Terebratula punctata *J. Sow.*	..	4	,,
,, sp.	..	2	,,
Cardinia *cf.* concinna (*J. Sow.*)	..	3	,,
,, ?	..	2	,,
Homomya ?	..	3	,,
Inoceramus ?	..	3	,,
Lima pectinoides ? (*J. Sow.*)	..	4	,,
Ostrea sp.	..	2, 3, 4	,,
Pecten (Chlamys) æquivalvis *J. Sow.*	..	4	,,
,, (Syncyclonema) liasianus *Nyst*	..	2, 3, 4	,,
Pholadomya sp.	1	..	..
Pleuromya costata ? (*Y. and B.*)	..	4	Spinatus.
Plicatula spinosa *J. Sow.*	1	..	..
Pteria (Oxytoma) cygnipes (*Phill.*)	..	2	Spinatus.
,, ,, inæquivalvis (*J. Sow.*)	..	3, 4	,,
Trapezium sp.	..	3	,,
Amaltheus turgidus *Hyatt*	..	4	,,
? Paltopleuroceras pseudospinatum (*Hyatt*)	..	4	,,
Belemnites sp.	..	2, 3, 4	,,

List of Localities.

1. South-eastern Scalpa. [H.B.W. 1014–1017.]
2. East coast of Strathaird; 600 yds. S. of Faoilean. [T. 4510–4557; C.B.W. 329, 330.]
3. East coast of Strathaird; about 350 yds. N. of Rudha Cruaidhlinn. [T. 4558–4590.]
4. S.E. coast of Strathaird; N. of first burn northward from Dun Liath. [T. 4350–4405; C.B.W. 408–429.]

iv. Upper Lias.

Genera and Species.	Strath-aird.	Ammonite Zones.
Plant remains	3	Communis.
Pentacrinus sp.	2	Communis.
Inoceramus sp.	1, ? 2	Communis—Serpentinus.
Ostrea sp.	1	Communis—Serpentinus.
Trochus ?	1	Communis—Serpentinus.
Dactylioceras angulatum (*J. Sow.*)	2	Communis.
,, *cf.* annulatum (*J. Sow.*)	1	Communis—Serpentinus.
,, braunianum (*d'Orb.*)	1	Communis—Serpentinus.
,, *cf.* ,,	1, 2	Communis—Serpentinus.
,, commune (*J. Sow.*)	1, 2	Communis—Serpentinus.
,, *cf.* gracile (*Simps.*)	2	Communis.
,, holandrei (*d'Orb.*)	1	Communis—Serpentinus.
,, *cf.* ,,	1, 2	Communis—Serpentinus.
,, *cf.* ,, *Wright* [non *d'Orb.*]	2	Communis.
,, raquinianum (*d'Orb.*)	1	Communis—Serpentinus.
,, sp.	1, 2	Communis—Serpentinus.
Harpoceras falciferum (*J. Sow.*)	1	Communis—Serpentinus.
,, *cf.* ,,	1	Communis—Serpentinus.
,, mulgravium (*Y. and B.*)	1	Communis—Serpentinus.
,, *cf.* strangwaysi (*J. Sow.*)	1	Communis—Serpentinus.
,, sp. nov.	1	Communis—Serpentinus.
Hildoceras walcotti (*J. Sow.*)	1	Communis—Serpentinus.
Paltopleuroceras sp. [fragment: remanié from Spinatus Zone ?]	1	Communis—Serpentinus.
Belemnites breviformis *Voltz*	2	Communis.
,, sp.	1	Communis—Serpentinus.

List of Localities.

1. Strathaird: east flank of Druim an Fhuarain; burn on hillside W. of raised beach, Faoilean. [T. 4691–4749; C.B.W. 651–653.]
2. S.E. coast of Strathaird: about 200 yds. S. of locality No. 4, Middle Lias (see above): base of sandstone cliff at high watermark; specimens are from nodular band forming bottom of oolitic ironstone and above carbonaceous shale. [T. 4406–4458.]
3. Same locality; shale under oolitic ironstone. [T. 4459–4462.]

v. Inferior Oolite.

Genera and Species.	Strathaird.	Ammonite Zones and Stratigraphical Groups.
Pentacrinus sp.	3, 7	Lower Parkinsoni, Group II.
Terebratula sp.	2	Group I.
Astarte sp.	4	,,
Lima sp.	2	,,
Modiola ?	3	Lower Parkinsoni. Group II.
Nuculana ?	3	Lower Parkinsoni. Group II.
Pecten (Chlamys) articulatus (*Schloth.*)	2	Group I.
Placunopsis jurensis (*F. A. Roem.*)	2	,,
Pleuromya ?	7	Lower Parkinsoni. Group II.
Pteria sp.	2	Group I.
Lamellibranchs, indet.	4	,,
Garantiana garantiana (*d'Orb.*) [or closely allied form]	5, 6	Lower Parkinsoni, Group II.
Stepheoceratid ammonite	5	Lower Parkinsoni, Group II.
Belemnites confertus ? *Tate*	4	Group I.
,, sp.	1	,,
Ostracoda	3, 7	Lower Parkinsoni, Group II.
Fish remains	7	Lower Parkinsoni. Group II.

List of Localities.

1. East coast of Strathaird; shore at Rudha Cruaidhlinn. [C.B.W. 407.]
2. River, 150 yds. N.W. of Kilmarie Lodge. [T. 4592–4627; C.B.W. 315–320, C.B.W. 342–347.]
3. River at Kilmarie, N.W. of foregoing locality; a few yds. W. of point where burn from N. enters main stream. [T. 4628–4644.]
4. South end of Strathaird; Rudha na h-Easgainne; east shore. [T. 4819–4828.]
5. Keppoch [Capach]; shale pit at easterly bend in road. [C.B.W. 391–400[1].]
6. Keppoch [Capach]; burn half-way between above shale pit and sandstone quarry further S. near end of fence. [C.B.W. 401–405.]
7. At bridge near School, Elgol: 6–8 ft. above bridge [T. 4785–4792]; 20–30 yds. above same bridge. [T. 4793–4818.]

vi. Great Estuarine Series.

Genera and Species.	Strathaird.	Strollamus.	Stratigraphical Groups.
Anomia æstuarina *Tate* . .	13	..	Cyrena Limestones.
Cyrena sp.	4, 13	..	Cyrena Limestones and Shales.
Cyrena-limestone . . .	..	24	Cyrena Limestones.
Cyrena ?	21	..	Cyrena Shales.
Ostrea hebridica *Forbes* . .	2, 8, 11, 14, 15	23, 25	Ostrea Beds.
,, ,, ? [altered limestone] . .	1, 3	..	,, ,,
Lamellibranchs [probably a Cyrena band]	6, 7, 20	22	Cyrena Shales.
,, [possibly Cyrena].	5, 9	..	Cyrena Shales and Limestones.
Viviparus *cf.* aurelianus *Cossm.* .	16	..	Cyrena Limestones.
? ,, *cf.* ,, . .	12	..	Paludina ,,
Viviparus scoticus (*Tate*) .	17, 19	..	,, ,,
,, sp.	13	..	Cyrena ,,
Viviparus-limestone [fossils ill-preserved]	10, 18	..	Paludina ,,
Estheria ?	13	..	Cyrena ,,
Ostracoda	12	..	Paludina ,,
Acrodus leiodus *A. S. Woodw.* .	12	..	,, ,,
Hybodus grossiconus *Ag.* . .	12, 13	..	Paludina and Cyrena Limestones.
,, polyprion *Ag.* . .	12	..	Paludina Limestones.
Fish scales	12	..	,, ,,
Chelonian [costal plate, etc.]	12	..	,, ,,
Reptilian bone fragments . .	12	..	,, ,,

List of Localities.

1. N. of Strathaird: lower eastern slope of Sgûrr-nan-Each, 270 yds. S. of B.M. 469·6 by Allt Aigeinn. [C.B.W. 383.]
2. S.E. slope of Sgùrr-nan-Each, a few yds. below lava. [C.B.W. 382.]
3. Burn about 750 yds. N.N.W. of lower waterfall in Allt na Dunaiche. [C.B.W. 309, 310.]
4. Just N. of lava patch on north side of Allt na Dunaiche. [C.B.W. 388–390.]
5. Allt na Dunaiche, 250 yds. E. of lower waterfall. [C.B.W. 325.]
6. Keppoch [Capach]; tributary stream flowing S.E., about 650 yds. E.N.E. of Strathaird House, and above road. [C.B.W. 326.]
7. Old pit by road running E. from Strathaird House, 170 yds. from junction with main road. [C.B.W. 327.]
8. Stream 50 yds. N. of stables, Strathaird House. [C.B.W. 328.]
9. New channel of Abhuinn Cille Mhaire, about 50 yds. E. of dam of new trout-loch, and 150 yds. W. of Free Church. [C.B.W. 341.]
10. East slope of Ben Meabost. [C.B.W. 375.]
11. Allt a' Ghoirtein, flowing S.E. between Ben Meabost and Ben Cleat, 430 yds. above road. [C.B.W. 380, 381.]
12. Coast N. of Elgol: shore between tide-marks and cliff at high water-mark at small promontory of limestone immediately S. of slipped mass of Càrn Mòr. [T. 4200–4244.]
13. Shore cliff S. of Glen Scaladal; N. of Càrn Mòr, Elgol. [T. 4310–4318.]
14. Shore cliff S. of Glen Scaladal; N. of Càrn Mòr. [T. 4326–4336.]

15. Same cliff about 300 yds. S. of mouth of Scaladal Burn. [C.B.W. 384.]
16. Shore between tide-marks just S. of mouth of Scaladal Burn. [C.B.W. 373.]
17. Glen Scaladal; tributary of Scaladal Burn, flowing from Ben Meabost. [C.B.W. 379.]
18. Coast between Rudha na h-Airidh Baine and Cladach a' Ghlinne. [C.B.W. 374.]
19. Camas Fhionnairidh; shore about 20 yds. N. of mouth of burn from Geal Ghillean. [C.B.W. 376–378.]
20. Burn 850 yds. N.E. of lower waterfall of Abhuinn nan Leac; about 60 yds. from lava scarp. [C.B.W. 387.]
21. Burn flowing into Abhuinn nan Leac on east side, 400 yds. N.E. of higher waterfall. [C.B.W. 386.]
22. Allt Strollamus, 40 yds. N. of junction with Allt na Teangaidh. [C.B.W. 442, 443.]
23. Allt na Teangaidh, 400 yds. N. of fault bringing in lavas. [C.B.W. 439–441.]
24. Allt Eoghainn, next burn eastward from Allt Strollamus, 200 yds. S. of road. [C.B.W. 444, 446.]
25. Same burn, 310 yds. S. of road. [C.B.W. 445.]

vii. Kellaways.

West side of Ben Cleat and S. of Càrn Mòr, near Elgol, Strathaird. From large blocks on shore. [T. 4164–4199.]

Ornithella kellowayensis (*Dav.*)
„ sp.
Rhynchonella *cf.* varians (*Schloth.*)
„ sp. nov. ?
Astarte sp.
Lima sp.
Pecten (Chlamys) fibrosus *J. Sow.*
Protocardia crawfordi (*Leck.*)
Pseudomonotis sp.
Trochus sp.
Kepplerites gowerianus (*J. de C. Sow.*)

viii. Upper Oxford Clay and Corallian.

Genera and Species.	Strathaird.	Strollamus.	South of Scalpa.	II. Higher beds (shale). I. Lower beds (sandstone).
Carpolithus conicus *Lindl.*	10	..	..	..
Plant remains	6	..	..	II.
Terebratula sp.	10	..	..	..
Grammatodon sp.	11	..	..	I. ?
Gryphæa sp.	6, 12, 13	..	..	I., II.
Lima sp.	6	..	..	II.
Modiola bipartita ? *J. Sow.*	10	..	..	..
Nucula ?	12	..	..	I.
Ostrea sp.	6	..	..	II.
Pecten (Camptonectes) *cf.* comatus *Münst.*	6, 10, 12, 13	..	..	I., II.
„ (Syncyclonema) demissus? *Phill.*	10	..	..	..
„ (Chlamys) fibrosus *J. Sow.*	1, 5, 6, 9	..	..	I., II.
„ (Syncyclonema) sp.	11	..	..	I. ?
Pholadomya *cf.* æqualis *J. de C. Sow.*	10	..	..	..
Pholadomya sp.	2, 8	..	..	I.
Pinna mitis *Phill.*	12	..	..	I.
Pleuromya ?	12	..	..	I.
Pseudomonotis *cf.* ovalis (*Phill.*)	9, 10	..	..	I.

Genera and Species.	Strathaird.	Strollamus.	South of Scalpa.	II. Higher beds (shale). I. Lower beds (sandstone).
Pteria (Oxytoma) inæquivalvis (*J. Sow.*) [=expansa *Phill.*] . . .	6, 10, 11	..	..	I. ?, II.
,, sp.	2, 8	..	..	I.
Velopecten sp.	16	..	..	I.
Lamellibranchs (Pecten ?, Cucullæa ?) .	..	..	24	II. ?
Ammonite, gen. indet.	7	..	..	..
Cardioceras cordatum (*J. Sow.*) . .	? 4, 11	..	..	I.
,, ,, (*d'Orb.*) pars [non *J. Sow.*] . .	8, 11, 21	..	..	I.
,, excavatum (*J. Sow.*) . .	12	..	..	I.
,, funiferum ? (*Phill.*) . .	10, 11	..	..	I. ?
,, nikitinianum ? *Lahusen* .	8	..	..	I.
,, *aff.* ,, . . .	11	..	..	I. ?
,, quadratoides (*Nikitin*) .	11	..	..	I. ?
,, quadratum ? (*J. Sow.*) .	21	..	..	I.
,, *cf.* ,, ...	6	..	..	II.
,, *cf.* rotundatum (*Nikitin*) .	8	..	..	I.
,, rouilleri*Lahusen*[non*Nikitin*]	8, 11, 12	..	..	I.
,, *cf.* ,, ,, ,, ,,	3	..	..	I.
,, suessi *Siemiradzki* . .	8, 11	..	..	I.
,, tenuicostatum (*Nikitin*) .	8, 15, 16, 21	..	..	I.
,, *cf.* ,, . . .	3, 10, 21	..	..	I.
,, *cf.* vertebrale (*Nikit.*) [non *J. Sow.*]. . . .	11, 18	..	..	I.
,, sp.	2, 19	22	24	I.
Perisphinctes laufenensis ? *Siemiradzki*	8	..	..	I.
,, mogosensis ? *Choffat* .	6	..	..	II.
,, pickeringius ? (*Y. and B.*)	6	..	..	II.
,, pseudoplicatilis ? *Siem.* .	14	..	..	I.
,, suevicus ? *Siemiradzki* .	6	..	..	II.
,, variocostatus ? (*Buckl.*) .	6, 21	..	..	I., II.
,, sp.	10, 16, 17	..	23	..
Belemnites abbreviatus *Mill.* . .	10	..	..	..
,, sp.	2, 4, 6, 10, 11, 20	..	23, 24	..

List of Localities.

1. Above Druim an Fhuarain, S.S.W. of Tobar Ceann. [C.B.W. 331.]
2. 550 yds. S.S.W. of Tobar Ceann ; stream below basalt. [C.B.W. 323, 324.]
3. Stream close under basalt scarp, 600 yds. S.S.W. of Tobar Ceann. [C.B.W. 338–340.]
4. Kirkibost ; stream 800 yds. N.N.E. of Free Church. [C.B.W. 332.]
5. Upper valley of Abhuinn Cille Mhaire ; a few yds. below fork of stream and waterfall where basalt appears. [C.B.W. 306.]
6. Same neighbourhood ; main stream at a point 50 yds. below fork of stream and waterfall. [T. 4660–4688.]
7. Same neighbourhood ; most northerly burn flowing into Abhuinn Cille Mhaire on west, below fork of stream and waterfall. [C.B.W. 352.]
8. Valley draining S.E. between Ben Meabost and Ben Cleat. [T. 4294–4308.]
9. Cnoc Breac, S. of Ben Cleat ; 600 yds. S.W. of sheepfold. [C.B.W. 353, 354.]
10. Càrn Mòr, Elgol ; from loose blocks on shore. [T. 4276–4293.]
11. Càrn Mòr, Elgol ; shaly sandstone (?) exposed above slipped mass. [T. 4245–4275.]

12. Càrn Mòr, west slope of Ben Cleat; cliff of shaly sandstone above southern part of slipped mass. [C.B.W. 360–367.]
13. West side of Ben Cleat; slope about 100 yds. S. of slipped mass. [C.B.W. 358, 359.]
14. Shore cliffs, S. of Glen Scaladal; N. of Càrn Mòr (either not in place, or from point 100 yds. higher up slope). [T. 4309.]
15. North slope of Ben Cleat. [C.B.W. 368.]
16. Glen Scaladal; north flank of Ben Cleat. [C.B.W. 355–357.]
17. Glen Scaladal; tributary of Scaladal Burn, flowing from Ben Meabost. [C.B.W. 349.].
18. Burn flowing from Beinn Leacach, close to mouth of Scaladal Burn. [C.B.W. 350.]
19. Cladach a' Ghlinne, mouth of Glen Scaladal; burn flowing S. from Beinn Leacach into Scaladal Burn, close to mouth of latter. [C.B.W. 438[1], 438[2].]
20. Coast S. of Rudha na h-Airidh Baine. [C.B.W. 351.]
21. On shore between tide-marks, Rudha na h-Airidh Baine, W. of Beinn Leacach. [T. 4337–4349.]
22. Allt Eoghainn, the burn next eastward from Allt Strollamus; western branch, short distance below Cretaceous limestone. [C.B.W. 448, 449, 465.]
23. South coast of Scalpa, E. of large dyke at mouth of Allt Stapaig. [C.B.W. 457–464.]
24. 20–50 yds. E. of mouth of Allt Stapaig; south coast of Scalpa. [T. 4829–4844.]

IX. Upper Cretaceous (*Pecten asper* Beds), South of Scalpa.

South coast: road-cutting opposite Sgeir Stapaig, and 130 yds. E. of mouth of Allt Stapaig. [C.B.W. 450–456; T. 4485–4509.]

Micrabacia ?
Exogyra *cf.* conica *J. de C. Sow.*
Lima ?
Pecten (Æquipecten) asper *Lam.*
Spondylus sp.

III. LIST OF SPECIES FROM RAISED BEACH DEPOSIT AT THE HEAD OF LOCH NA DAL, SKYE.

By Mr. Thos. Scott, F.L.S.

MOLLUSCA.

Pecten maximus (*Linné*).
Montacuta bidentata (*Montag.*).
Lucina borealis (*Linné*).
Cyamium minutum (*Fabr.*).
Cardium edule *Linné.*
,, fasciatum *Montag.*
Mytilus edulis *Linné.*
Venus lincta (*Pult.*).
Tapes pulastra (*Montag.*) *var.*
Saxicava rugosa (*Linné*).
Patella vulgata *Linné.*
Trochus cinerarius *Linné.*
Lacuna divaricosta (*Fabr.*).
Littorina obtusata (*Linné*).
Littorina littorea (*Linné*).
Rissoa parva (*da Costa*).
,, ,, *var.* interrupta (*Adams*).
,, violacea *Desm.*
,, striata (*Adams*) *var.* aculeus *Stimps.*
,, albella *var.* sarsii *Lov.*
Skenea planorbis (*Fabr.*).
Homalogyra atomus (*Phil.*).
Cæcum glabrum (*Montag.*).
Odostomia insculpta (*Montag.*).
,, interstincta (*Montag.*).
,, ,, *var.* intermixta.
,, minima *Jeff.*
Cerithium reticulatum (*da Costa*).
Nassa.
Utriculus umbiculatus (*Montag.*).

OSTRACODA.

Aglaia complanata *B. and R.*
Pontocypris mytiloides (*Norm.*).
Cythere lutea *Müller.*
,, confusa *B. and N.*
,, crispata *G. S. B.*
,, macallana *B. and R.*
,, albomaculata *Baird.*
,, convexa *Baird.*
,, tuberculata (*G. O. Sars*).
,, concinna *Jones.*
,, pellucida *Baird.*
,, angulata (*G. O. Sars*).
,, cuneiformis *G. S. B.*
,, whitei (*Baird*).
,, villosa (*G. O. Sars*).
Loxoconcha impressa (*Baird*).
,, pusilla *B. and R.*
Xestoleberis depressa (*G. O. Sars*).
,, aurantia (*Baird*).
Cytherura cornuta (*G. S. B.*).
,, acuticostata *G. O. Sars.*
,, undata *G. O. Sars.*
,, nigrescens (*Baird*).
,, cellulosa *Norm.*
Cytherois fischeri (*G. O. Sars*).

ECHINODERMATA.

? Echinocardium cordatum (*Penn*).
? Echinus esculentus *Linné.*

FORAMINIFERA.

Miliolina aglutinans (*d'Orb.*).
Textularia gramen *d'Orb.*
Verneuilina polystropha (*Reuss*).
Bulimina marginata *d'Orb.*
,, elegans *d'Orb.*
,, fusiformis.
Bolivina punctata *d'Orb,*
,, plicata *d'Orb.*
Lagena lævis (*Montag.*).
,, semistriata *Will.*
,, squamosa (*Montag.*).
,, globosa (*Montag.*).
,, lucida (*Will.*).
,, Williamsoni (*Alcock*).
,, lævigata (*Reuss*).
,, costata *Will.*
Polymorphina compressa *d'Orb.*
,, oblonga *d'Orb.*
,, gibba *d'Orb.*
Patellina corrugata *Will.*
Planorbulina mediterranensis *d'Orb.*
Truncatulina lobatula (*W. and J.*).
Rotalia beccarii (*Linné*).
,, nitida (*Will.*).
Gypsina inhærens *Schultze.*
Nonionina depressula (*W. and J.*).
Polystomella crispa (*Linné*).
,, striatopunctata (*F. and M.*).

Remarks.—The Raised Beach material sent to me for examination has yielded a few interesting things, especially amongst the small Mollusca and Ostracoda. My friend, Mr. J. T. Marshall of Torquay, S. Devon (one of the foremost British authorities on the micro-mollusca), to whom I submitted a few of the more doubtful forms, remarks that the *Odostomia minima* and the *Rissoa striata* var. *aculeus*, are very interesting, and that both occur in the Belfast deposit. He also further states that the var. *intermixta* of *Odostomia interstincta* is a form not hitherto separated from the type, though it has been known for some time. Among the Ostracoda the following are of interest: *Aglaia complanata* has been obtained in only a few places—chiefly in Ireland. Though recorded as a recent species, the specimens obtained may have been fossil as no living, or recently dead, specimens appear to have been observed. *Cythere macallana*, though widely distributed, is not a common species. It has been recorded from the Clyde Post-Tertiary beds. *Cythere whiteii* is also moderately rare both as a recent and fossil species. *Cytherura cellulosa* is a curious little species that was discovered by Dr. A. M. Norman many years ago, and is now known to be widely distributed. The Echinoderm remains consist of small fragments of the test and a few spines; these remains represent two distinct forms, and appear to belong to the species to which I have referred them.

With regard to the bathymetrical distribution of the various organisms mentioned in the lists, I can only venture the remark that with very few exceptions they may all be found living either in the "Littoral" or the "Laminarian" Zones, that is to say, from the shore down to 8 or 10 fms. None of them are true deep-water species, and most may be obtained alive in water that is quite shallow: indeed, the *Littorinas* recorded and the *Cardium edule* are only usually to be found between tide-marks or little below that

Thos. Scott.

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